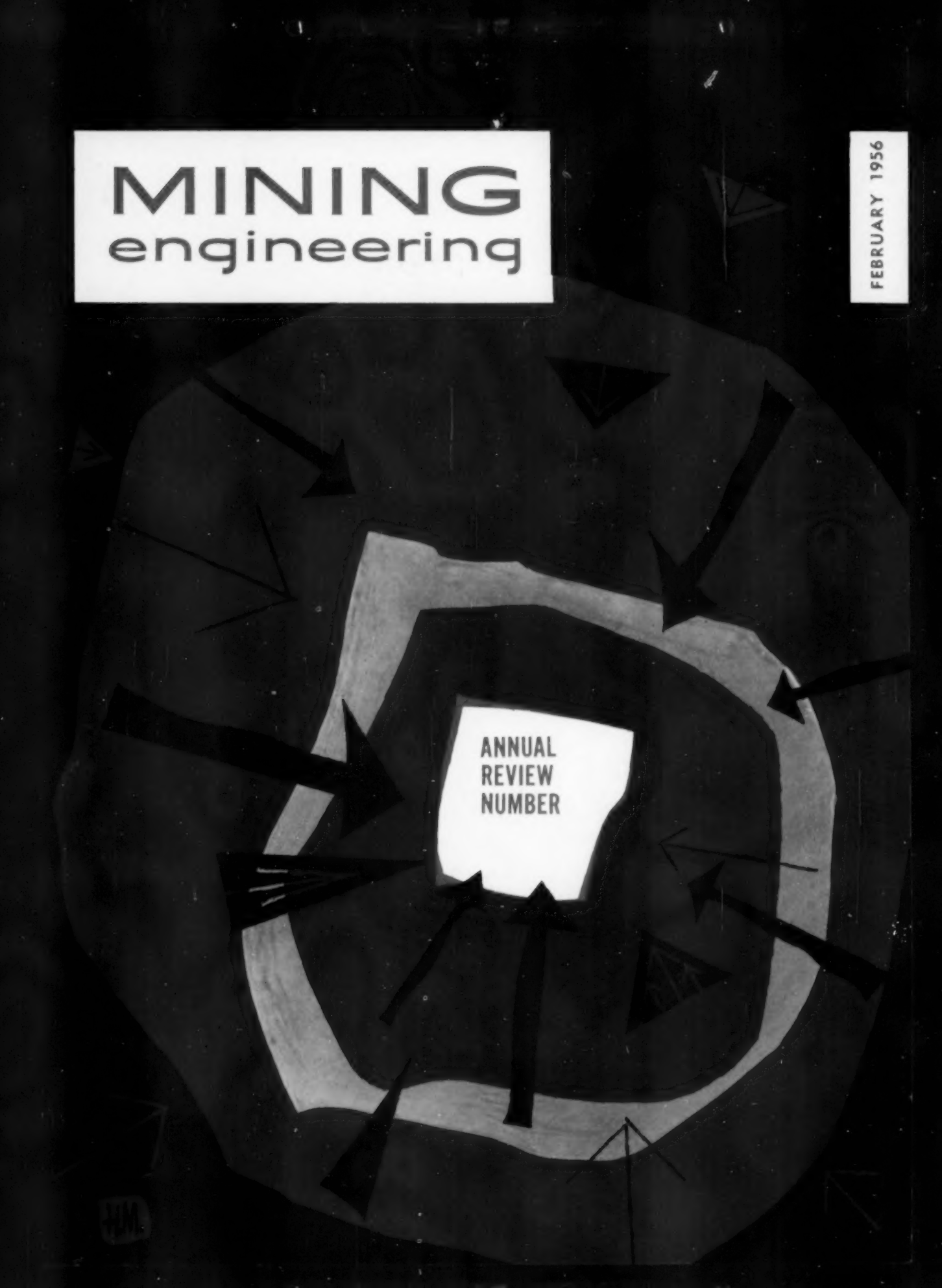
MINING engineering

FEBRUARY 1956



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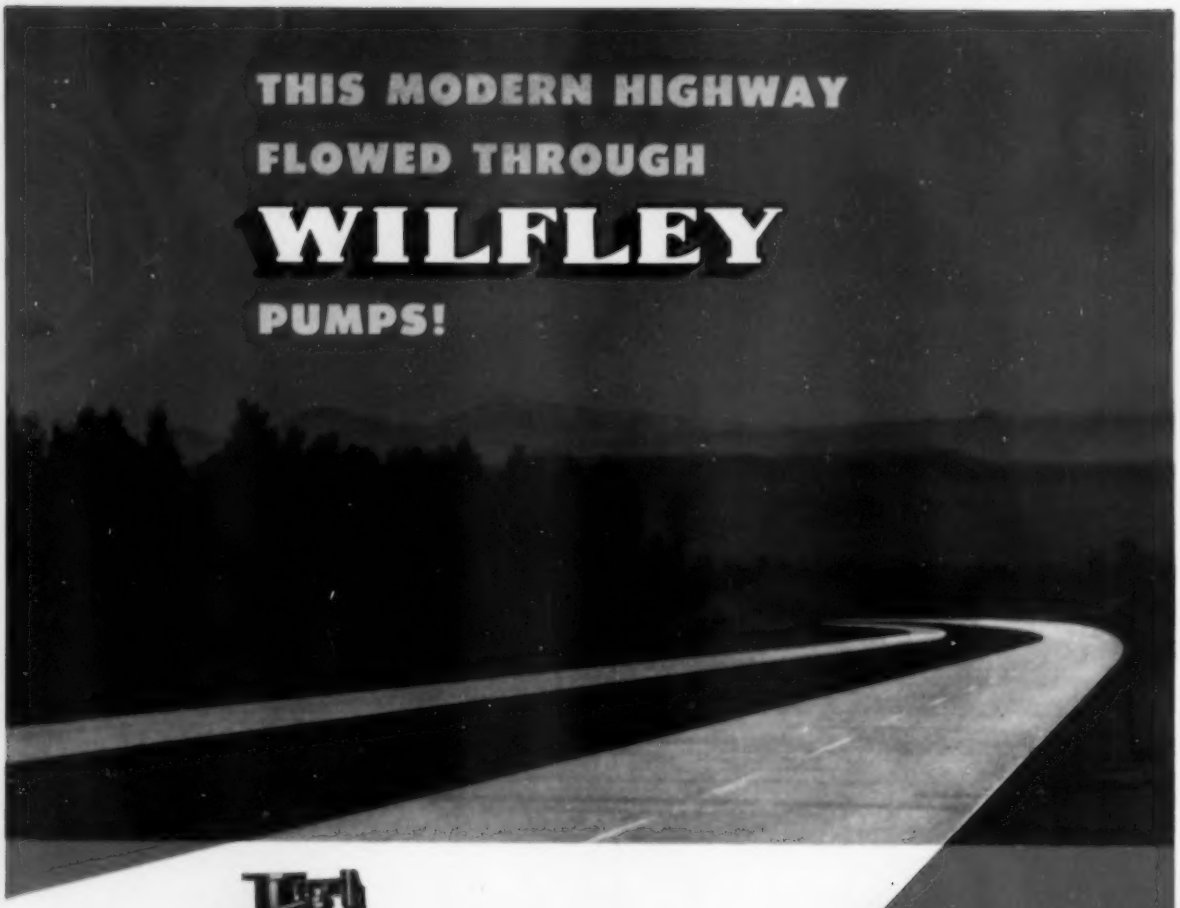

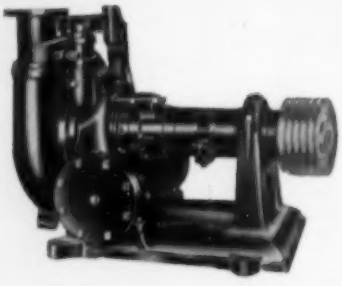

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MINING engineering

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THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

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POSITIONS OPEN

Mining Engineer, young, to assist superintendent in graphite mine. Will involve shaft sinking, etc. Some correspondence. Must speak Spanish. Salary open. Location, Mexico. W2633.

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(Continued on page 102)

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Spencer prilled Ammonium Nitrate is key ingredient in new "make-it-yourself" explosive

By F. M. Robertson, Supt., DeBardeleben Coal Corporation

During one year of testing Akremite, the new "make-it-yourself" explosive, we of the DeBardeleben Coal Corporation at Sipsey, Alabama, have had the following experiences:

(1) We can cut blasting costs as much as 50%. (2) Better fragmentation permits stripping units to move 25% more materials per hour. (3) A dramatic series of tests has proved that Akremite is one of the safest possible explosives.

This simple but revolutionary new explosive is the brainchild of R. L. Akre, superintendent of drilling at Maumee Collieries Co., Terre Haute, Ind., using prilled Ammonium Nitrate produced by Spencer Chemical Company.

Ammonium nitrate by itself is not an explosive. But it was Akre's idea to mix ammonium nitrate with carbon black and pack it in a polyethylene bag. When the bag is confined in a drill hole and detonated with a high gelatin dynamite and primacord, it produces a tremendous explosion. Because the mixing operation is so simple and safe, it can be done right at the mine location.

To find out how safe Akremite actually is, we asked Southern Research Institute at Birmingham to put the new explosive through a series of tests. The testers fired bullets into bags of freshly made Akremite. They also conducted the regular pendulum-friction and modified propagation-through-air tests.

No explosions, fire, or crackling resulted from any of these tests, although the rifle-bullet impact test on dynamite produced four violent explosions out of four trials.

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(NOTE: Spencer Chemical Company will be happy to provide you with further information about the Akremite Method as discussed by Mr. Robertson.)

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GM DIESEL
CASE HISTORY No. 556-188

OWNER: Badgett Mine Stripping Corporation, Madisonville, Ky.

INSTALLATION: GM "6-110" Diesel-powered Bucyrus-Erie 3-yard shovel loading fleet of GM Diesel-powered Euclid rear dumps on Pennsylvania Turnpike extension project.

PERFORMANCE: Partner Brown Badgett says GM Diesels are "doing a wonderful job." He's running his shovel 10 hours a day, plans to start 24-hour operation soon.

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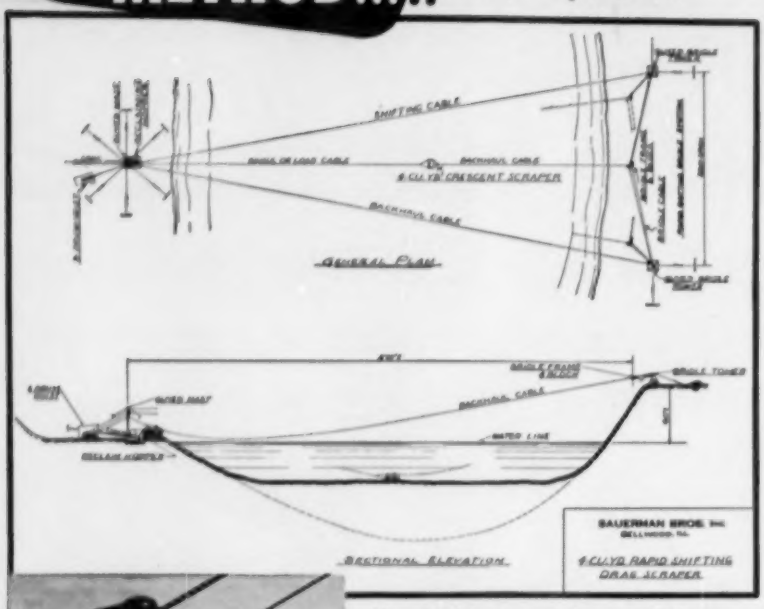

Above drawing was prepared for a specific drag scraper installation and does not represent maximum spans.

View shows rapid shifting bridle frame and all operating cables. Crescent may be seen in background conveying load to reclaiming hopper just in front of mast.

•

Contact Sauerman's engineering department for specific recommendations and information. No obligation.

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(Continued from page 98)

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Mining Engineer, young, with underground experience, for surveying, mapping, etc. with metal mining company. Salary open. Location, South. W1725.

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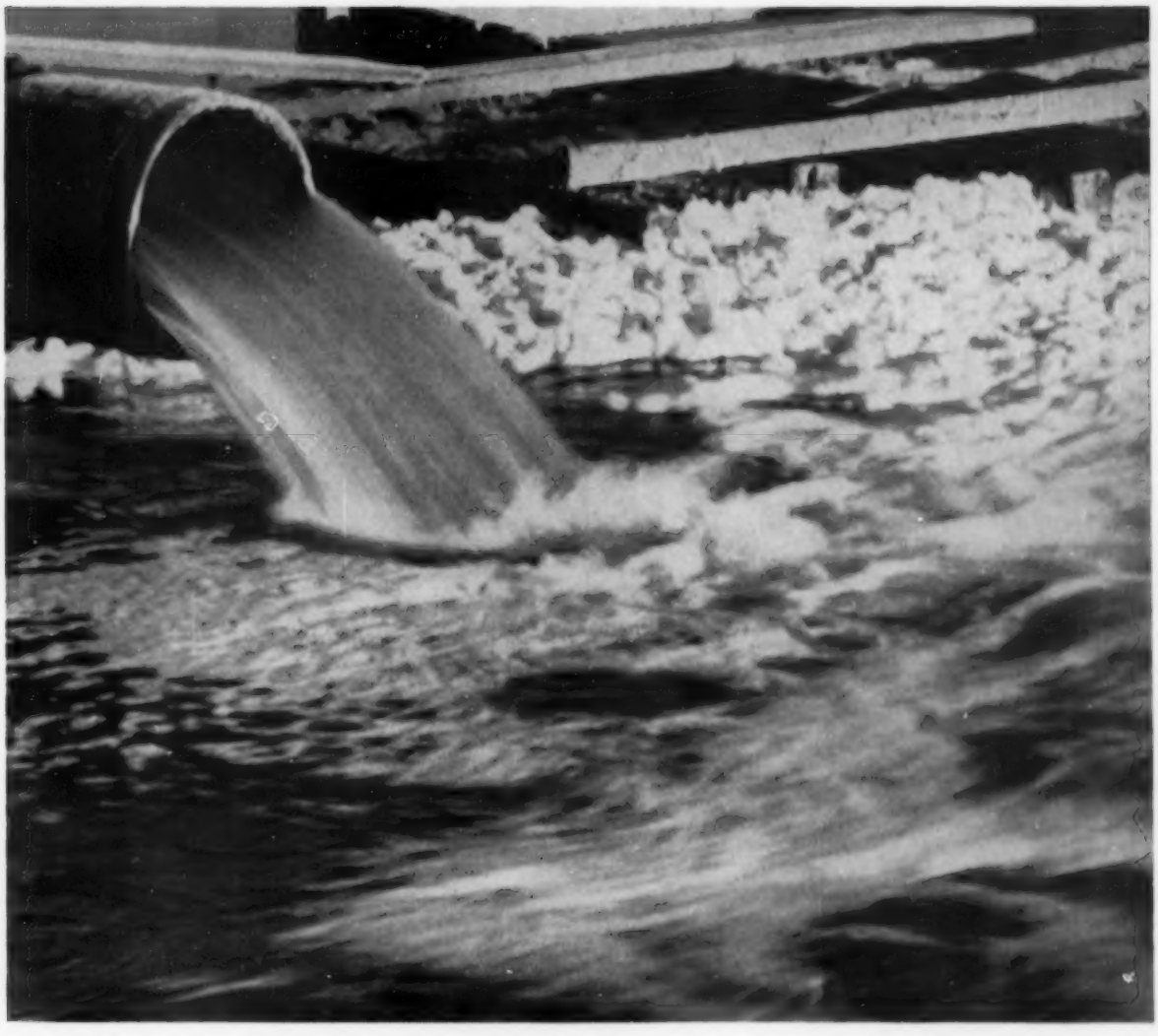

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La Construction des Tunnels, Galeries et Souterrains, by Georges Bardout and Pierre Berny, *Editions Eyrolles,* Paris, available in the U.S. from Stechert-Hafner, 31 E. 10th St., New York 3, N. Y., approximately $10.25, 287 pp., 1954.—A comprehensive treatment of tunnel construction covering planning, excavation methods, timbering, blasting, shield and compressed air operations, sintering of caissons, etc. Separate chapters are devoted to the description of equipment, to the necessary calculations, and to the evaluation of costs. Some notable tunnels are briefly described and a group of detailed diagrams of typical projects is appended.

Preliminary Report on Uranium in Hardin County, Illinois, by J. C. Bradbury, M. E. Ostrom, and L. D. McVicker, Circular 200, 3¢ postage, 21 pp., 1955. **Unpublished Reports on Open File,** I. Minerals Fuels, by Margaret B. Brophy, Circular 201, 2¢ postage, 9 pp., 1955. **Sizing Studies on Pilot-Oven Coke, Comparison with Commercial Coke Size,** by H. W. Jackman and R. L. Eissler, Circular 202, 2¢ postage, 7 pp., 1955. **Uranium in Illinois Black Shales,** by M. E. Ostrom, M. E. Hopkins, W. A. White, and L. D. McVicker, Circular 203, postage 2¢, 15 pp., 1955. These circulars are free of charge, except for postage, from the *State Geological Survey Div.,* 121 Natural Resources Bldg., University of Illinois Campus, Urbana, Ill.

Safety in Coal Mines, Volume II—Legislation, *International Labor Office,* Washington Branch, 917 15th St., N.W., Washington 5, D. C., $3.50, 647 pp., 1955.—Because of the enormous quantity of coal mining legislation, the selection here has been confined to Belgium, Canada, France, West Germany, the Netherlands, the Union of South Africa, the United Kingdom, and the U. S. Volume I provided statistical material showing the incidence and chief causes of underground accidents in coal mines, together with a description of administration, inspection, and general safety activities in nine coal producing countries.

Uranium in the Northwest, Mineralized Areas and Prospecting Suggestions, by Leonard D. Jarrard and Wayne S. Moen, *Published by the Authors,* P.O. Box 136, Butte, Mont., $3.00, 93 pp., 1955.—The authors state that the occurrences in their book have been observed by them in the field and that the facts are drawn from first-hand examinations. Their book tells what lands may be prospected, lists known occurrences, suggests areas for prospecting, and describes rock favorable for uranium. Advice is given on instruments, prospecting, and claim staking. Among other things, the appendices contain price schedules, laws and regulations, publication lists, and a glossary. The book is well illustrated with maps and photographs. There is even a sample of autunite to check a Geiger counter and there are location notices in the back of the book waiting to be torn out and posted. Both the authors are geologists with the Div. of Raw Materials, AEC.

Possibilities for Discovery of Additional Lead-Silver Ore in the Palomas Camp Area of the Palomas (Hermosa) Mining District, Sierra County, New Mexico, A Preliminary Statement, by Richard H. Jahns, *New Mexico Institute of Mining and Technology,* Campus Station, Socorro, N. M., Circular 33, free, 14 pp., area map, 1955.—The author is professor of geology, California Institute of Technology.

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World Economic Report, 1953-54, *United Nations*, available from Columbia University Press, 2960 Broadway, New York 27, N. Y., $1.75, 152 pp.—This is considered by many to be the most important economic study made by the UN. Part I covers domestic economies, centrally planned economies, and under-developed countries. Part II covers changes in international trade and payments. The 1954 economic recession in the U. S. and reasons for its mild repercussions are discussed. Factors underlying the increase in production and trade of Western Europe and consequences of changes in economic policy in Eastern Europe are also reviewed.

1955 Book of ASTM Standards, Part I—Ferrous Metals, *American Society for Testing Materials*, 1916 Race St., Philadelphia 3, Pa., $13.50, 1834 pp., 1955.—Included are standard and tentative specifications, test methods, and definitions for steel piping materials; flat products; bars, bolts, and rivets; billets, forgings, and axles; concrete reinforcement; corrosion-resisting steel; metallic coatings for steels; magnetic materials; ferroalloys; and metal powders, as well as general methods of testing.

Tin 1954, A Review of the World Tin Industry, *International Tin Study Group*, 7, Carel van Bylandtlaan, The Hague, Holland, $1.00, post free, 56 pp., 1955.—This period was one of general stability. Production showed little change; consumption increased; prices were steady. Illustrated with 23 charts. Tables and estimates for the USSR are not given.

Glossary of Selected Geologic Terms, with special reference to their use in engineering, by William Lee Stokes and David J. Varnes, *Colorado Scientific Society*, paper bound $2.75, cloth bound $3.50, 165 pp., 1955.—Nongeologic users should find this glossary of more than 2600 geologic terms interesting as well as useful. Yet it is technical rather than popular. It is intended primarily for civil engineers and specialists in related fields. The authors are with the U. S. Geological Survey.

Mining Explained in Simple Terms, *Northern Miner Press Ltd.*, 116 Richmond St. W., Toronto 1, Ont., $3.00 Can., 162 pp., 1955.—An excellent book for the layman written by the editorial staff of *The Northern Miner* and well known experts in special fields. The chapters on elementary and economic geology are written in clear, everyday language. Scientific prospecting, diamond drilling, sampling, mine workings, and milling are concisely described and generously illustrated with sketches and photographs. There is an extensive glossary of common mining terms and a chapter containing advice to the investor.

NAYLOR

...the "Shortest Line" Between Two Points

When you need air or water *fast*, the quick way to get what you want is through lines of Naylor Spiralweld pipe. Naylor pipe is light in weight so it's easy to handle, easy to install. You can put it to work in a hurry—even in rough going—especially with the Naylor one-piece Wedge-Lock coupling to speed connections. That's why in mining service, you'll find Naylor "the shortest line" between points. Sizes range from 4" to 30" in diameter, with wall thicknesses from 14 to 7 gauge. Bulletin No. 507 tells the story about this distinctive light-weight pipe and coupling combination. Write for it today.

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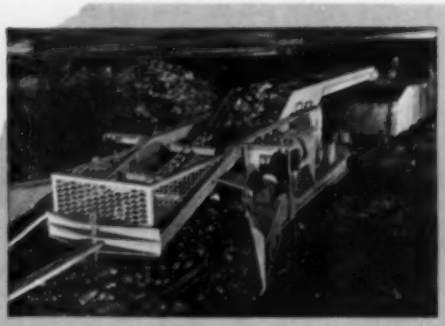
Magic Performance

PILES UP SAVINGS...

When you are expected to pull profits out of your hat, just turn to American Mine Door profit-making equipment.

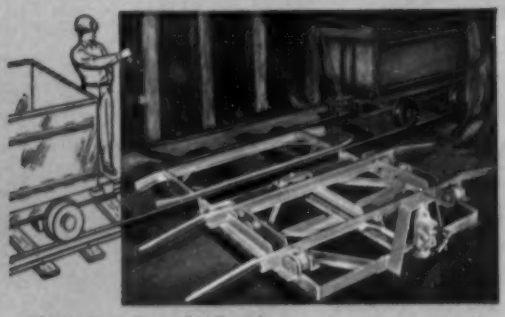


"Canton" Track Cleaners

Model 30 designed for low coal . . . Model 40 for the average mine. Keep road beds clean, saving thousands of dollars per month. Now rendering spectacular performance in coal, iron, copper, potash and salt mines . . . tailor-made to your specifications.

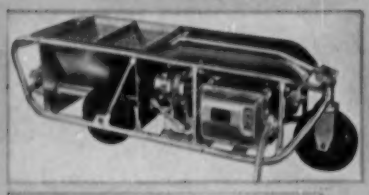
"Canton" dependable switch thrower

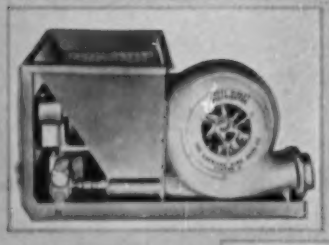
Make extra profits with extra speed. No jumping on and off trips . . . man hours, man lives saved . . . more tons taken out . . . greater profits per shift. Reliable "American Mine Door" mechanism.



"Canton" Air Power Car Transfer

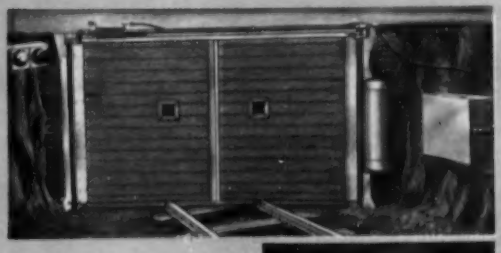
Now Air Power is added to the money-saving Car Transfer. One man does the work of three. Loads entire train on a single track. Less rib to shoot than for jump switch . . . no hazards of cherry picker. Air Power now 50% faster. Can be installed on your present hand model.





"Canton" Rock Dusters

"Canton" Little Chief goes anywhere . . . rubber tired model 32½" high, or skid model 18½" high, for shuttle buggies, bolts or mine cars, or track-mounted for haulage roads. Delivers 34 to 60 lbs. dust per minute through 50 to 400 ft. 1¼" hose. "Canton" Mighty Midget weighs only 280 lbs. . . . quickly moved to dust rooms as soon as loading machine departs. Ideal for small mines . . . inexpensive, can be cart-mounted . . . big capacity . . . 7 tons per shift. (The Track Mounted Hi-Pressure "Dustmaster" is still the greatest Dustributor ever built, described in brochure.)

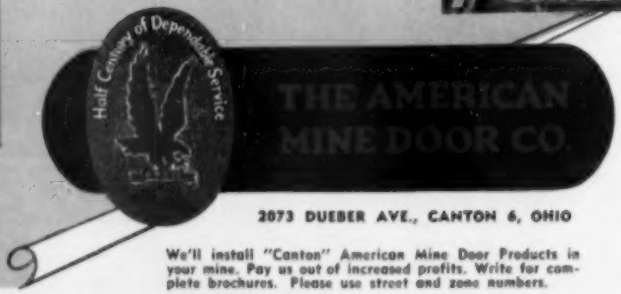


"Canton" Mechanically Operated Doors

First, the "Canton" mechanical door, not subject to power failure, famous for half a century . . . NOW the "Canton" Air Power Door with overhead operating equipment, BOTH effect tremendous savings by allowing full speed, profitable trips, eliminating accident potential of hand doors.

"Canton" Cable Splicer and Vulcanizer

"Canton" Cable Splicers are greatest reducer of down time. Every machine man should carry a pocketful. Just pound around cable and go on working. No special tools. Used with vulcanizer in shop makes new, smooth, seamless splice strong as original cable.



2073 DUEBER AVE., CANTON 6, OHIO

We'll install "Canton" American Mine Door Products in your mine. Pay us out of increased profits. Write for complete brochures. Please use street and zone numbers.

Gardner-Denver . . . Serving the World's Basic Industries

Push production...protect personnel... with Gardner-Denver Mine Car Loaders

For the job: Powerful crowding action—utilizing both 5-cylinder air motors—fills the dipper in any muck pile. Fast discharge loads long mine cars to brim. Wide clean-up.

For the man: Easy-to-reach, easy-to-work controls. No clothes snagging gadgets on the outside. Rail-hugging stability, due to low center of gravity and high-flange wheels.

Send for information.

GARDNER - DENVER

THE QUALITY LEADER IN COMPRESSORS, PUMPS, ROCK DRILLS AND AIR TOOLS FOR CONSTRUCTION, MINING, PETROLEUM AND GENERAL INDUSTRY

Gardner-Denver Company, Quincy, Illinois
In Canada: Gardner-Denver Company (Canada), Ltd., 14 Curity Avenue, Toronto 16, Ontario

THE AEROFALL MILL

grinds and crushes in a single operation

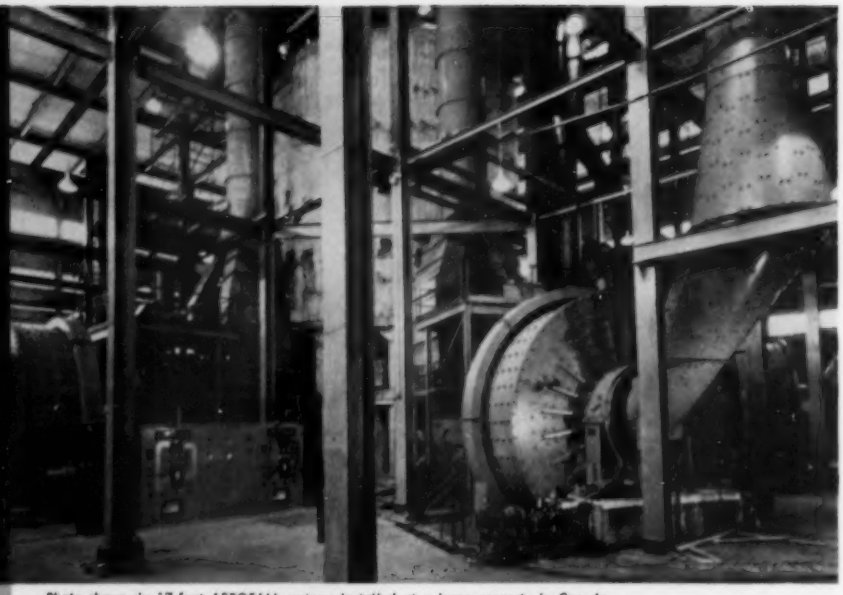


Photo shows six 17-foot AEROFALL systems installed at a large property in Canada.

COMPACT

The AEROFALL system is compact, requires less floor space than conventional crushing-grinding equipment and lowers considerably the cost of buildings, foundations and initial installations.

OPERATES UNDER POSITIVE VACUUM

A clean system, it operates under positive vacuum in a completely closed circuit eliminating need for any additional plant dust-control apparatus. This closed vacuum system has proved safe in the reduction of quartzite to silica products, which if allowed to escape into the plant would be extremely hazardous to personnel.

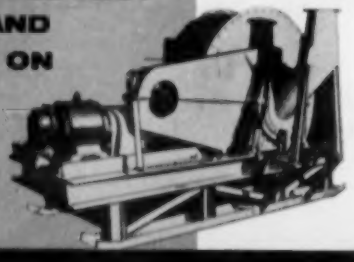
TOUGH WEAR-RESISTANT

AEROFALL Mill liners are cast in tough, wear-resistant material for a long operating life. Normal life per set is two to three years with wear at 0.10 to 0.30 pounds per ton.

COMPLETELY AUTOMATIC

Electronic controls make operation completely automatic and continuous, hence one man can handle a group of AEROFALL MILLS. BULLETIN 55A contains a complete description of this unique process, its advantages and savings to you.

AEROFALL PORTABLE TEST MILL AND DRIVE ON BASE



To predetermine which size AEROFALL Mill best suits any particular mineral-recovery operation, we have available portable units. Test mill needs approximately 17 ft. x 30 ft. x 14 ft. height.

After a representative sample is processed in the Aerofall mill the test products and a report are returned to be evaluated. Any firm interested in improving the economics of its mineral-dressing process can profit by an AEROFALL test unit and its operator.

Write for your copy of BULLETIN 55A today.

AEROFALL MILLS, INC.

1025 WEST THIRD AVE., COLUMBUS 8, OHIO, U.S.A.

AEROFALL MILLS, LTD., 129 ADELAIDE ST., W., TORONTO, CANADA AFRICAN AEROFALL (PTY) LTD., MARITIME HOUSE, JOHANNESBURG, S. AFRICA

Manufacturers News

News
Equipment
Catalogs

• FILL OUT THE CARD FOR MORE INFORMATION •

Hydraulic Attachments

Caterpillar No. 12 motor grader is shown below with new hydraulic attachments. These include hydraulically shiftable moldboard, hydrau-

lically operated snow plow and bulldozer mounting, and hydraulically actuated snow wing. Attachments on the No. 12 are the same for the No. 112 motor grader. **Circle No. 1.**

Dust Control

The *Johnson-March Corp.* hydro precipitator scrubber removes microscopic solids, fumes, and odors from exhaust gases. Unit collects dust by hydro-compressing exhaust gases through a system of multiple tubes into a water chamber. Efficiency up to 99 pct is claimed with dust loadings at 5 g per cu ft and 70 pct of the material below 5 mu. Scrubber comes in 15 sizes for capacities ranging between 500 and 40,000 cfm. **Circle No. 2.**

Concrete Gunning Rig

Air Placement Eqpt. Co. has a portable concrete gunning rig. The three basic pieces are: concrete gun; automatic proportioning, dry mixing, and elevating machine; and a

sand loader. Entire unit may be hitched to either the air compressor or if the compressor is mounted on a truck, to the trailer hitch of the truck. **Circle No. 3.**

Panelboards

Crouse-Hinds Co. has developed explosion-proof and dust-tight panelboard for dangerous locations and for installations where corrosive vapor, noncombustible dust, or moisture is present. These Condulet assemblies, functioning either as load centers or panelboards, provide circuit protection on wiring systems up to 120 v. **Circle No. 4.**

Air Meter

The *Soiltest* Techkote air meter is a multirange testing instrument that increases the usefulness of the air meter. With one instrument it is possible to measure—within a fraction of a degree—entrained air of numerous materials such as lightweight concrete, mortar, plaster and soil, in addition to regular concrete. **Circle No. 5.**

Structural Panel

Brauer Engineering Co. makes a structural aluminum panel with specially grooved edges that confine side laps to panel tops and prevent

side lap leakage. Grooved edges and 4-in. depth of section permit roofs to be completely flat or at any pitch without additional roof-covering materials. No special tools are needed. **Circle No. 6.**

Remote Control TV

To provide safety in hazardous locations, Dage Television Div., *Thompson Products Inc.*, has a remote control closed-circuit TV system. The multilens TV camera is directed entirely by a separate monitor-console. By turning the appropriate knob, lenses are changed, focusing is set, and the camera is directed up or down, right or left. **Circle No. 7.**

Heavy Duty Vise

For bending heavy iron bars *Athol Machine & Foundry Co.* has a 150-lb semisteel vise. Each jaw has a gripping surface of 5x4 in. with a depth of about 6 in. For maximum holding

power for freeing nuts and fittings, jaw facing has a full 5-in. long pipe grip to take ⅛ to 6-in. diam pipe or rod. Vise can be left out of doors permanently. **Circle No. 8.**

Materials Handling

The *Frank G. Hough Co.* 1955 HAH Payloader features two-wheel drive and 1-cu yd capacity. Bucket breakout action permits 40° tipback at ground level. A larger ver-

sion of the HA model, it has a breakout force of 4500 lb, a 4000-lb lifting capacity, and a 3000-lb carrying capacity at 4 mph. Lift is 7 ft 9 in. **Circle No. 9.**

Rock Bits

Brunner & Lay Inc. has added a 600-thread series to its carbide-insert Rok-Bit line. The 3½, 3, 2¾, and 2½-in. X design bits are said to eliminate rifling. Bits fit directly on

G-D extension rods with no need for expensive adapters. Five air holes facilitate chip removal and keep bit from working in its own cuttings. **Circle No. 10.**

35-Ton Truck Crane

Marion Power Shovel Co. states that the model 43-MR truck crane will carry its maximum rated load with outriggers at a radius of 15 ft. Other features of the rubber-mounted unit include: dual front axles, power-removable counterweight, and a 180-in. wheelbase for greater maneuverability. **Circle No. 11.**

News & Notes

Aktiebolaget Atlas Diesel of Stockholm, Sweden, has changed its name to *Atlas Copco Aktiebolag*. In the U. S. the Atlas companies will be known as *Atlas Copco Eastern Inc.*, with headquarters and general offices in Paterson, N. J., and *Atlas Copco Pacific Inc.* of San Carlos, Calif.

Cut down man hours! Speed up hole drilling!

2 new more powerful Thor wagon drills!

General purpose SW-1 • Heavy duty BW-2

Now Thor offers two new wagon drills to fit every drilling requirement — wagon drills which will outperform and out-last other models. Drill holes in any direction, at any angle, on level or sloped ground. One man operation cuts costly man hours. Check these features on the new heavy duty BW-2 and the general purpose SW-1 and then call your Thor contractors tool distributor for a free trial of the model that fits your job.

THOR SW-1

Compact size—3 wheel reinforced rig • Weight with model 75 drifter—768 lbs. • 2 handle controls movable along mast • Handles up to 3½" bore drifter • New centralizer swings out of way for close drilling • Mast swings 360° vertical or horizontal • Wet or dry operation

THOR BW-2

5 h.p. rotary air motor • 3 wheel reinforced heavy-duty rig • Variable speed control • Motor and controls movable along mast • Wet or dry operation • Mast swings 360° vertical and horizontal • New centralizer swings out of way for close drilling • 800 to 1000 lbs. pulling power for steel removal • Spring buffer prevents chain breakage • Equipped with Thor 105 drifter. (4" bore)

Thor
PORTABLE POWER
TOOLS

THOR POWER TOOL COMPANY, AURORA, ILL.

Atlanta, Birmingham, Boston, Buffalo, Chicago, Cincinnati, Cleveland, Denver, Detroit, Houston, Los Angeles, Milwaukee, Newark, Long Island City, N.Y., Philadelphia, Pittsburgh, St. Louis, San Francisco, Seattle, Toronto Canada: Export Division, New York City

(21) RUBBER LINING: Manhattan Rubber Div., *Raybestos-Manhattan Inc.*, has a 12-page catalog on corrosion, abrasion, and contamination-resistant rubber linings for tanks, pipe, valves, and similar storage and process equipment. Given are solutions and lining recommendations, useful tables, and other data.

(22) WIRE ROPE INSPECTION: *Tyer & Co. Ltd.* has a folder on the Tyer-Integra wire rope crack detector for checking interior flaws and breakage. Device may be moved along wire rope or the rope moved within the detector. Variations in magnetic flux are amplified and registered on a recorder.

(23) FIRE ARMOR: Available from *Johns-Manville* is a 12-page booklet, "Asbestos Safety Clothing." Shown are asbestos suits, helmets, aprons, leggings, overshoes, and the Wearbestos line of gloves and mittens. These are specially treated to increase their resistance to heat, oil, water, and abrasion.

(24) PORTABLE & UNIT MILLS: Bulletin M5-B5 from *Denver Eqpt. Co.* contains flowsheets and photographs of mills from 5 to 7 tph, 7 to 10 tph, 25 to 125 tph, and 100 to 200 tph. Also shown are portable placer units, portable cyanide and gold mills, a package coal flotation unit, and a mobile laboratory.

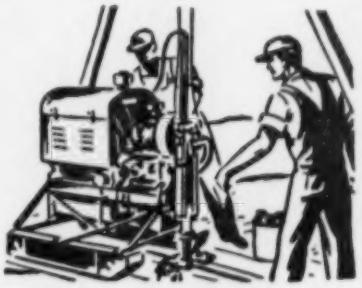
(25) WIRE ROPE FITTINGS: Bulletin 164 from *Sauerman Bros.* contains tables, drawings, and ordering information for open and double wedge sockets in rope sizes from ⅜ to 2 in.

(26) HARDNESS CONVERSION TABLES: Small celluloid card from *International Nickel Co.* contains hardness conversion tables for steels. Shown is the approximate relationship between Brinell, DPH, (Vickers), Rockwell and Shore Scleroscope hardness values and corresponding tensile strengths of steels. Data from SAE Handbook.

(27) HOSES & DUCTS: Concerned with dust collection, fume control, air conditioning, and materials handling? Bulletin 60 contains information and prices on *Flexaust* hoses and Portovent ducts.

(28) CONCRETE FORM COATING: *Stonhard Co.* has a 6-page folder on a liquid resin coating for concrete forms used in construction. It is claimed to be more economical than penetrating bases or special lacquers.

(29) DIAMOND DRILLING: Catalog 400 from *Sprague & Henwood* illustrates a wide variety of accessory equipment for diamond drilling



and soil sampling. All essential items are in stock for prompt delivery. Catalog gives piece numbers and shipping weights.

(30) CONCRETE BREAKAGE: Folder from *Brunner & Lay* gives details of the Sabur point, a pneumatic tool accessory for concrete breaking. Wedge action permits tool to continue its penetration with point riding free.

(31) FOR BULK MATERIALS: *Beaumont Birch Co.* has a catalog on Dura-Tred chains and Beaumont drive wheels for bucket elevators and conveyors. They are guaranteed when operated over plain traction or company's Trac-Pull wheels to handle bulk materials at less cost per ton.

Free Literature

(32) CRAWLER TRACTOR: Technical and operating features of the 45 drawbar hp HD-6 diesel-powered crawler tractor are given in catalog MS-461 from *Allis-Chalmers*. Also listed are matched equipment and accessories that increase efficiency and economy, and provide maximum safety and comfort for the operator.

(33) PROCESS PUMPS: In *Ingersoll-Rand's* bulletin 7004-B on vertically split, single-stage, and two-stage process pumps, a 2-page chart shows the extensive interchangeability of parts. Units have a range from 1 to 8 in. including capacities to 3200 gpm and heads to 925 ft at temperatures to 800°F.

(34) TURBO-DOZER: The Construction Machinery Div. of *Clark Eqpt. Co.* has a 20-page booklet on the Michigan model 180 Turbo-Dozer. More than 50 photographs arranged in film clip fashion illustrate operation and correct application.

(35) MULTI-V BELTS: *B. F. Goodrich* has a data sheet on Multi-V belts. Said to last 20 to 50 pct longer, they have all the load carrying cords concentrated in twin grommets or cord loops. They are like giant twisted cables except that they are endless.

(36) SILICONES: Available from *Dow Corning Corp.* is the 1956 reference guide to silicone products. Nearly 150 are listed, 18 of which were first introduced within the last 12 months.

(37) GRATING: *Klemp Metal Grating Corp.* has an illustrated report on steel, aluminum, and stainless grating and stair treads. Brochure also discusses bridge decking and various types of anchors suggested for grating installation.

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

2

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after May 15, 1956—if mailed in U. S. or Canada.

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41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64						

Students should write direct to manufacturer.

(38) VACUUM VALVES: Bronze, cast iron, and fabricated steel bellows-sealed vacuum valves are shown in bulletin 401 from Kinney *Mfg. Div., New York Air Brake Co.* Valve disk, top gasket, and bellows are easily replaced without breaking vacuum manifold.

(39) DIG-LOAD-CONVEY: Bulletin from *Barber-Greene Co.* is illustrated with on-the-spot photographs of ditchers, crawlers, bucket loaders, conveyors, car unloaders, and other material handling equipment.

(40) DUST COLLECTION: Constant dust collection at full-rated capacity is guaranteed with Norblo automatic bag-type arresters. Bulletin 164-4 from *Northern Blower Co.* explains the unit's compartment system with its automatically controlled progressive and cyclic bag cleaning.

(41) SHALLOW SEISMIC DATA: Bulletin S-303 from *Houston Technical Laboratories* features the portable High Resolution seismic system. This equipment makes possible reflection surveys over a depth range of 100 to 2500 ft. It is designed for use in petroleum exploration, mining, ground water location, and civil engineering where shallow seismic information is vital.

(42) MINE CAR LOADER: *Gardner-Denver* has information available on the GD10 mine car loader. It has a 4¾-cu ft dipper, a low center of gravity, and high flange wheels for stability on the rails. With only two points to oil regularly, it is "engineered to go underground and stay."

(43) TRACTORS—SCRAPERS: Form 31690 from *Caterpillar* covers the 300-hp DW20 and DW21 tractors. Their matched Lowbowl scrapers have capacities of 18 cu yd struck and 25 cu yd heaped. Tractors have a 10 pct increase in rimpull, turbocharged engine with direct electric or gasoline engine starting, and wide-section tires.

(44) LUBRICANTS: Bulletin 105 from *Alpha Molykote Corp.* has information on Molykote type 165X, the open gear lubricant, and Molykote Loex, a lithium base lubricant with a temperature range—100° to 250°F. Prices are included.

(45) MAGNETIC DRUMS: Illustrated in bulletin MD-200 from *Homer Mfg. Co.* are permanent magnetic drums. In the processing of chemicals, minerals, sand, coal, cement, slag, ore, etc., these nonelectric drums automatically remove tramp iron or ferrous material from gravity or conveyor transported products.

(46) 3 TO 15-TON CRANES: *Whiting Corp.* has an 8-page illustrated catalog on "E" type cranes that offer advantages comparable to many custom-built installations. These overhead traveling cranes are particularly valuable in industries where cranes are used intermittently or where high speed lifting and travel are not essential.

(47) VIBRATING SCREENS: Form 652 from *Pioneer Engineering Works* shows typical applications of 11 standard sizes of single-mounted and four standard combination sizes of tandem-mounted vibrating screens. In addition to data tables on capacities, booklet also has information on washing attachments, spouts, chutes, and hoppers.

(48) ROPE AND CHAIN FITTINGS: *American Hoist & Derrick Co.* has a 28-page catalog 950-1 on fittings for wire rope and chain. Given are dimensions, safety factors, and other data.

(49) ROOF BOLTS: Bolt & Nut Div., *Republic Steel Corp.*, has a folder on wedge head mine roof bolts suitable for either stoper driven or auger drilled holes. Bolts can be installed in holes ⅛ in. diam oversize or 1/16 in. diam undersize.

(50) PIPES & FITTINGS: *Alpha Plastics* has two folders on unplasticized, rigid pvc corrosion-resistant pipe. The first shows proper selection where high chemical resistance and/or high impact resistance is desired. Companion folder covers threaded and socket solvent cement fittings.

(51) DIESEL POWER: More than 150 different manufacturers pick GM diesel power for more than 850 different models of equipment they build. Information from Detroit Diesel Engine Div. of *General Motors* will show you why.

(52) ORE ANALYZER: Uranium-thorium analyzer, described in *Tracerlab's* bulletin M-106, consists of a scintillation detector and a Geiger tube. One takes beta count; other reads gamma only. This "equilibrium technique" is said to result in rapid, accurate assays without wet chemical analyses.

(53) CENTRIFUGAL FANS: Greater efficiencies with less horsepower are claimed by *Chicago Blower Corp.* for its airfoil centrifugal fans. They are said to be especially applicable to forced and induced draft systems.

(54) ION EXCHANGE: Available from *Rohm & Haas Co.* is a bimonthly report, "Amber-Hi-Lites." See advertisement, page 103. Current issue describes uranium determination.

(55) GYRATORY CRUSHER: For bulletin on *Kennedy-Van Saun* crushing machinery and equipment. See page 101.

(56) MINE CAR COUPLER: For information on *Mayo's* mine car coupler. See page 224.

(57) VIBRATORY FEEDERS: For complete data from the *Syntron Co.* See page 123.

(58) BELT FASTENERS & RIP PLATES: For bulletin F-112 from *Flexible Steel Lacing Co.* See page 230.

(59) LOG WASHER: For catalog 55 from *Eagle Iron Works.* See page 231.

(60) MILLING: For bulletin 55A from *Aerofalls Mills Inc.* See page 110.

(61) VENTILATION: For catalog 55 from *American Brattice Cloth Corp.* See page 232.

(62) LIGHTWEIGHT PIPE: For bulletin 507 from *Naylor Pipe Co.* See page 107.

(63) PUMPS: For catalog 5206 from *Nagle Pumps Inc.* See page 226.

(64) FEEDERS: For information on the *Simplicity* Os-A-Veyor feeders, grizzly feeders, horizontal screens, or gyrating screens. See page 133.

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MINING ENGINEERING

29 WEST 39th STREET

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Hard, Rough, Tough Jobs Need Eimco Dependability

This case study concerns one Eimco 105 loader on which an open pit mine depends for its entire production.

Location — in an isolated and remote area of Southwest Africa.

Conditions — dusty, dry and hot. Pit floor uneven-solid rock.
Mining — selective
Operators — native
Maintenance — Nil

Report — The Eimco 105 Tractor Excavator has operated some 3200 hours on consecutive two shift basis under the most difficult conditions. Native operators are unnecessarily abusive of the equipment. The ore is exceptionally abrasive and heavy. No other loading equipment is available so the Eimco must stay on the job. One operator ran the 105 a complete shift without fan belts, both of them run the machine to the solid rock wall and spin the tracks when cleaning out an ore pocket.

Eimco does not recommend abuse on their tractor-excavators or any other equipment but Eimco produces a machine that can stay on the job day in and day out—month in and month out—when you are depending on it and when plant capacity depends on a single production loading unit.

There are many reasons for Eimco superiority on the tough jobs. The design of an Eimco is simple-strong. The material of construction is all alloy steel. The operating features make it the easiest tractor to operate and the most maneuverable. When you need guts in a tractor, compare an Eimco with anything you are using or have used previously.

THE EIMCO CORPORATION

Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City

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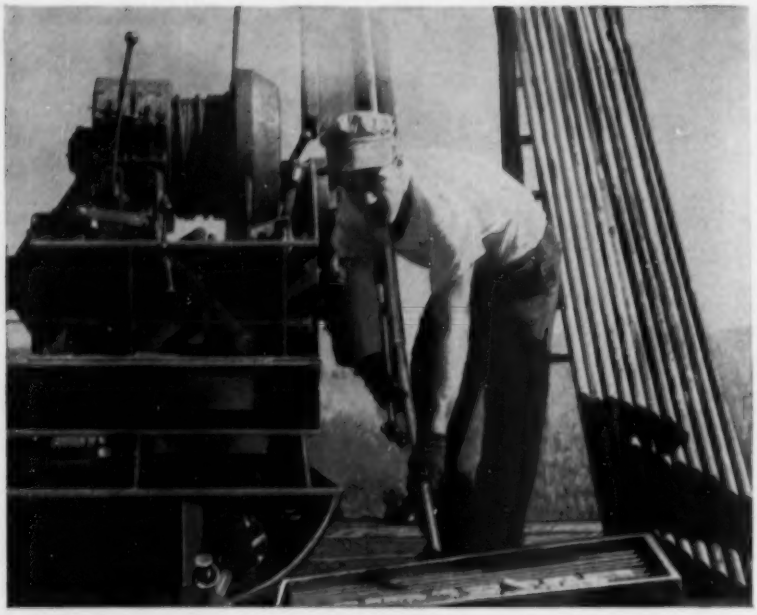
B-173



CONTRACT DRILLERS

SINCE 1883

Founded more than seventy years ago, in the heart of the then rapidly-expanding anthracite industry, Sprague & Henwood, Inc. pioneered many important developments in Diamond Core Drilling that have stood the test of time.

During this long period of successful operation our crews have completed thousands of drilling contracts, in all parts of the United States and in many other countries. Satisfactory results were secured in some cases where other drillers failed, through the use of special equipment designed by our experienced excutives and built in our own extensive shops.

Today, we have a large force of expert operators and an ample supply of modern equipment, so that we can undertake practically any job, anywhere, on short notice. Inquiries for all types of contract drilling work are solicited — estimates submitted promptly without charge or obligation.

SPRAGUE & HENWOOD INC., Scranton 2, Pa.

NEW YORK • PHILADELPHIA • PITTSBURGH • GRAND JUNCTION, COL. • BUCHANS, NFLD.
EXPORT REPRESENTATIVE, PHILIPS EXPORT CO., 100 EAST 42nd STREET, NEW YORK, N.Y.

NEW LIGHT-WEIGHT HIGH-SPEED CORE DRILLING MACHINES
Model 30 and Model L-2

Supplementing our well-known line of heavy-duty machines for large-diameter and deep-hole drilling we now offer two light-weight high-speed core drilling machines suitable for either Skid, Trailer or Truck mounting. Both models can be powered by either gasoline or diesel engines and air or electric motors. Easily moved from one location to another, they can also be relied upon to produce good smooth cores rapidly at minimum expense.

Standard single-pole derrick permits pulling rods or casing up to 10-ft. lengths

Modern simplified design includes convenient controls, machine-cut alloy-steel gears, anti-friction bearings and other improved features to assure low-cost trouble-free operation. Write for illustrated leaflets containing complete descriptions and working data.

Model 30, Truck Mounted

Complete drilling rigs, mounted on 4-wheel-drive trucks with capacity for carrying accessory equipment and supplies.

MODEL 30 TRAILER MOUNTED

for easy portability without tying up a truck.

MODEL 30 SKID MOUNTED

for jobs not easily accessible by truck or trailer. Wide structural-steel base and low center of gravity provide ample stability.

Leading Manufacturers of High-Speed Diamond Core Drilling Machines, "Oriented" Diamond Bits and a complete line of Improved Accessory Equipment for Core Drilling and Soil Sampling. Write for illustrated catalogues containing complete specifications and all necessary working data on:

Auger Bits, all types
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Drive Pipe
Drive Pipe Couplings
Drive Shoes
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Fishtail Bits
Flush Coupled Casing
Foot Safety Clamps
Hoisting Hooks
Hoisting Plugs
Hoisting Plug Reducers
Hoisting Rings
Hose, Waterswivel
Hose, Suction
Jar Lengths
Jaws, Safety Clamp
Lifters, Rod
Mud Bits
Pilot Reamers
Plugs, Hoisting
Pressure Testers
Protectors, Casing
Reamer Shells
Reducers, Rod
Rods, Drill
Rod Couplings
Rod Taps
Rope Sits
Safety Clamps
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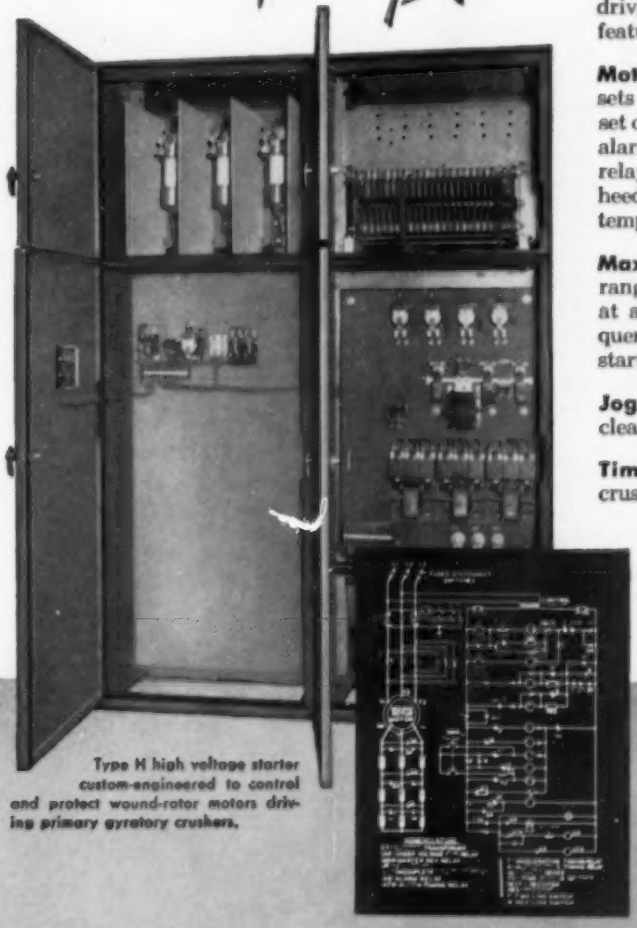
CUT CRUSHER DOWN-TIME

with Custom-Engineered

ALLIS-CHALMERS

CONTROL



Type H high voltage starter custom-engineered to control and protect wound-rotor motors driving primary gyratory crushers.

Allis-Chalmers has built and installed hundreds of gyratory crushers in the past 75 years. Drawing on this experience, A-C engineers have developed a control circuit designed to cut costly down-time in the rough-tough job of rock and ore crushing. This control circuit is considered by rock products operators to be the ultimate in control and protection for wound-rotor motors driving primary gyratory crushers. Here are some features of this circuit:

Motor Overload Protection — Two separate sets of thermal overload relays are provided. One set operates on slightest overload to sound remote alarm horn and energize indicating light. These relays do not stop motor. If warnings are not heeded, a second set of relays stops motor when temperature reaches danger point.

Maximum Torque Starting — Control is arranged so that maximum torque can be obtained at any time while motor is being started. Frequently, application of maximum torque permits starting a stalled crusher and clearing jam.

Jog-Reversing Controller permits rocking to clear jam.

Time-Delay Undervoltage Relay allows crusher to ride through momentary voltage dips.

Stall Protection — On currents greater than normal load peaks, the motor is disconnected through an instantaneous current relay.

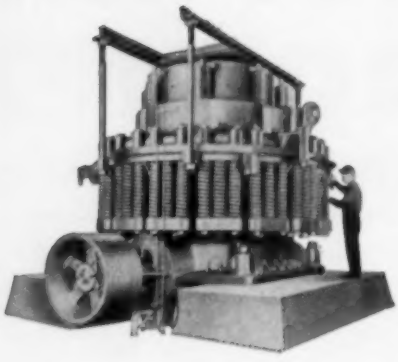
Write for details. Explanatory material is yours for the asking. See your A-C representative or write Allis-Chalmers, Milwaukee 1, Wisconsin.

A-4525

ALLIS-CHALMERS

SYMONS® PRIMARY GYRATORY CRUSHERS... Built in sizes from 30" to 72" feed openings to meet any desired production operation.

SYMONS CONE CRUSHERS... The machines that revolutionized crushing practice. Built in sizes from 22" to 7' diameter heads with a wide range of capacity.



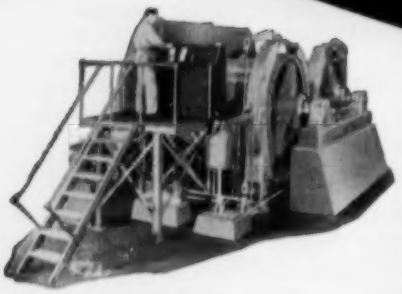
NORDBERG MACHINERY for the MINING INDUSTRY

For base metals...precious metals ...the rarer elements...non-metallics and minerals . . . NORDBERG MACHINERY is the outstanding choice of producers in the mining industry the world over.

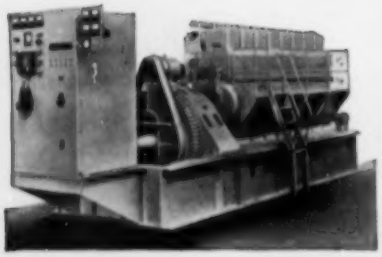
More than half a century of progressive engineering achievement, combined with quality production, in unexcelled manufacturing plants, have firmly established Nordberg's leading position in the field of heavy machinery design and construction.

Nordberg Machinery assures maximum and continuous production at low operating and maintenance cost. For full details, write for literature on the machinery you need.

NORDBERG MFG. CO.
Milwaukee, Wisconsin

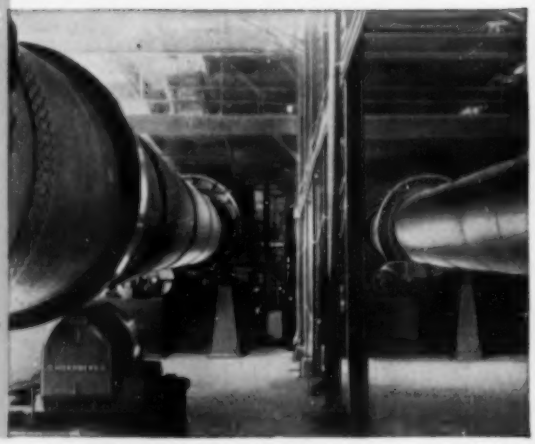


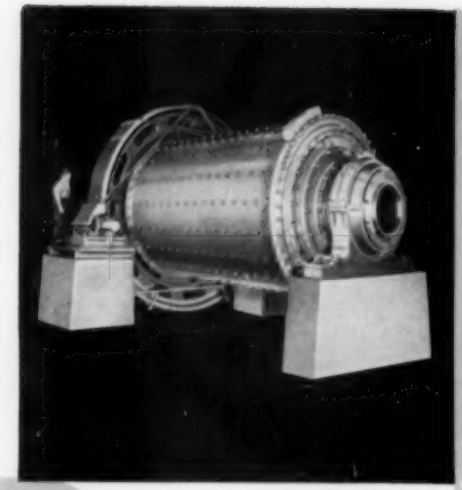
NORDBERG MINE HOISTS... As the source of the most progressive hoist engineering advances in the mining industry, Nordberg has held worldwide leadership in the hoist field since 1895.



NORDBERG ENGINES . . . For oil, gas or Duafuel® operation. Built in sizes from 10 to over 10,000 horsepower to meet practically all power requirements.

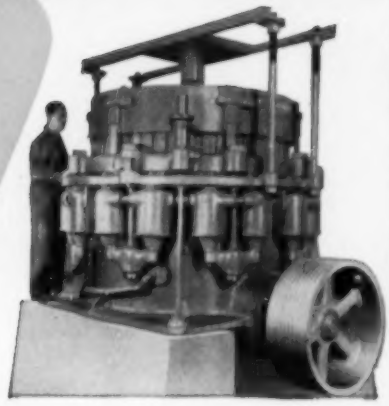
NORDBERG KILNS — DRYERS and COOLERS... To meet a wide range of requirements, including pyro processing operations, drying, calcining burning and cooling.





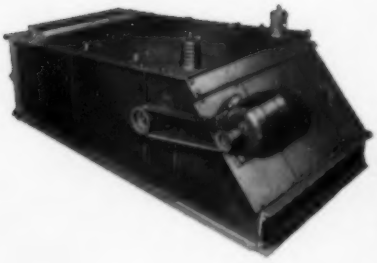
NORDBERG GRINDING MILLS . . . Ball, tube, rod and compartment types for wet or dry, open or closed circuit operation.

SYMONS VIBRATING GRIZZLIES . . . Built in bar and rod types for effective heavy duty scalping service handling feed sizes up to 30" and larger.



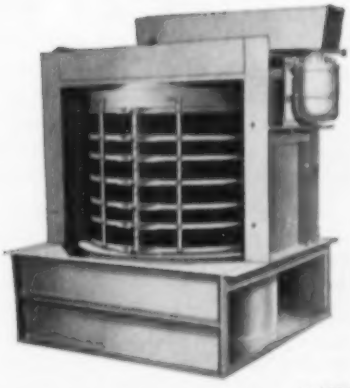
NORDBERG GYRADISC CRUSHER . . . A revolutionary machine for the production of large tonnages of extremely fine product.

SYMONS HORIZONTAL VIBRATING SCREENS . . . Level position assures extreme accuracy in sizing, requires less headroom, permits easy installation.



SYMONS ROD DECK SCREENS . . . Highly efficient screening surface of spring steel rods—easily replaced. Especially suited for wet, sticky materials.

SYMONS "V" SCREENS . . . For extremely fine, single cut wet or dry separations. Employs controlled diffused feed and vertical flow of material.



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M 155-R

NORDBERG MACHINERY

NORDBERG

MACHINERY FOR PROCESSING ORES and INDUSTRIAL MINERALS

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SYMONS . . .

A REGISTERED NORDBERG TRADEMARK KNOWN THROUGHOUT THE WORLD

Virtually all mining areas now standardize on Clarkson stainless steel units to accurately feed reagents to flotation cells. In 1939, Miami Copper Company, Miami, Arizona, was first of the Copper Concentrators to install stainless steel feeders. These early units still provide maintenance-free service for Miami Copper.

Stainless steel units good as new after 17 years of corrosive reagents

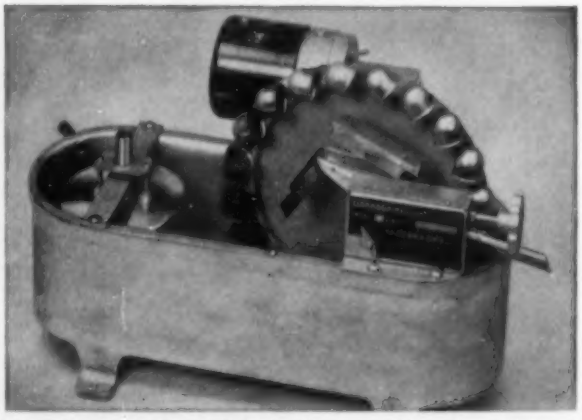
FLOTATION is an operation where the earning-power of stainless steel comes to the top.

Reagent feeders operating since 1939 still give good-as-new performance because they're made entirely of austenitic chromium-nickel stainless steel.

Regardless of where you operate, whether in nonmetallic or metallic mining, there are hundreds of applications where chromium-nickel stainless steel will pay off handsomely.

As in feeders, stainless steel containing nickel lengthens equipment life. It resists attack by chemicals and atmospheres over a wide range of concentrations, pressures and temperatures. What's more, it is strong, tough, and ductile. Its high resistance to impact, wear and abrasion spells long, maintenance-free service under severest operating conditions.

There's no need to put off using stainless steels where you want long, money-saving performance. Leading steel companies produce austenitic chromium-nickel stainless steels in all commercial forms.



No replacements needed despite years of service under corrosive and abrasive conditions on units such as this. View shows interior of durable, corrosion-resistant 18-8 chromium-nickel stainless steel feeder, developed and produced by Clarkson Co., a Division of Equipment Engineers, Inc., San Francisco.

INCO TRADE MARK **THE INTERNATIONAL NICKEL COMPANY, INC.** 67 Wall Street New York 5, N.Y.

Uranium and Thorium Developments

Competitive bidding will be instituted for leasing uranium deposits developed by the AEC on lands it controls. Existing lessee selection system, based on experience and financial status, was established because previously classified information on uranium reserves could not be divulged on invitations to bid. With production from privately owned properties at a high level, it is likely that only a few AEC deposits will be offered for lease in the near future. . . . A uranium ore-buying station and sampling plant was opened by the AEC at Tuba City, Ariz., February 1. The station will be turned over to its owner, Rare Metals Corp., upon completion of this firm's adjacent mill this summer. . . . A semiportable uranium ore-buying station of limited capacity will be opened by AEC near Grants, N. M., on April 1. It will serve the area pending construction of milling facilities. . . . AEC will sell thorium metal for $19.50 per lb to enterprises to use for peacetime applications.

Kennecott Acquires New Brunswick Properties

Kennco Explorations (Canada) Ltd., a subsidiary of Kennecott Copper Corp., has acquired some 500 mining claims in New Brunswick, about 20 miles southwest of the American Metal Co. properties. Two drillholes reportedly have shown ore similar to previous lead-zinc discoveries in the area. Kennco is preparing a diamond drilling campaign to determine the extent of orebody.

Anaconda Investments in Chile

President Carlos Ibañez of Chile has authorized The Anaconda Co. to invest $38 million to increase production at Chuquicamata by 45,000 tons a year and to construct workers' homes. Anaconda will submit another program to the Chilean Government designed to bring the Indio Muerto properties in Tarapaca Province into production.

British Coal Production Falls

British 1955 coal output, which totaled almost 250 million net tons, was more than 2 million tons below the disappointing 1954 figure. To meet domestic requirements some 12 million tons were imported, largely from the U. S. One reason for the bad showing was a decrease of 5000 coal miners. The modernization program, started several years ago, is progressing slowly and is requiring a considerable number of miners for development work. The program will not be completed before ten years, but by this time some 80 pct of British coal will be dug in virtually new mines. The Government is encouraging the use of oil and has a project for building 12 nuclear power stations, but little change in the supply situation is expected during 1956.

IN VENEZUELA . . . AND THE WORLD OVER

It's Bucyrus-Erie For the Tough Metal Mining Jobs

When the rich iron ore deposits of Cerro Bolivar mountain in Venezuela were discovered, Bucyrus-Erie 190-B shovels were selected to spearhead the job of excavation. Swinging 8-cu. yd. dippers, they keep a fleet of 20-cu. yd. carriers on the move.

The proved superiority of Bucyrus-Erie large-capacity excavators is the result of new front-end design, extra-strong construction, and advanced engineering throughout. Combined with the speed and smoothness of Ward Leonard electric control, these features offer performance that means higher output at the lowest cost per yard.

36155C

GLOBAL APPROVAL
MOROCCO • PHILIPPINES • RHODESIA • UNITED STATES • VENEZUELA • ALGERIA • CANADA
110-B 4½-cu. yd.
150-B . . 6-cu. yd.
190-B . . 8-cu. yd.
BUCYRUS ERIE
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Bucyrus-Erie Company

South Milwaukee, Wisconsin

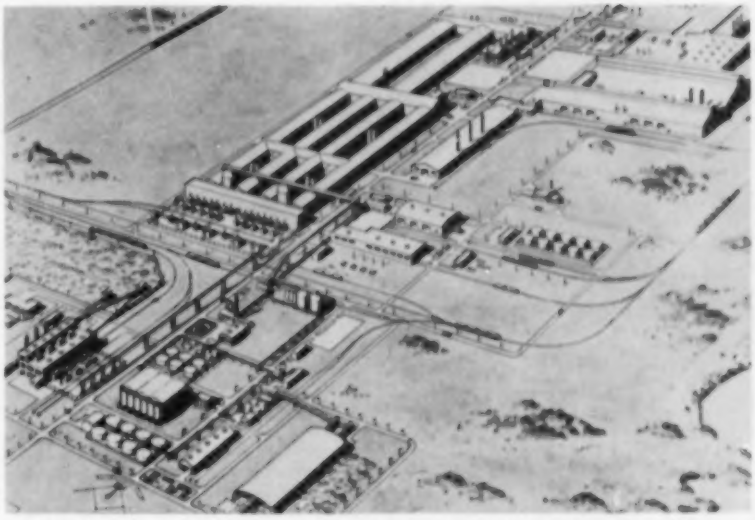
Olin Mathieson Enters The Aluminum Industry

Ohio Plant Will Use Power From Coal

Olin Mathieson Chemical Corp. plans to enter the aluminum industry with an initial investment of $120 million, and with the world's first fully integrated aluminum plant. The new operation marks the first time in the history of the aluminum industry that coal mined directly on the site will be used to provide the major power requirements for alumina reduction.

Investment in the new operation includes approximately $90 million for the aluminum plant and $30 million for the related power facilities. The aluminum plant will be financed from the company's own resources and a newly negotiated $60 million long-term loan from Prudential Insurance Co. The power plant will be financed entirely through a $30 million loan from Prudential to the power subsidiary corporation, in which Olin Mathieson will have a 50 pct interest.

The alumina plant, reduction plant, and rolling mill will be on the Ohio River near Clarington, Ohio. The power plant to be engineered and built by American Gas and Electric will be slightly upstream on the West Virginia side at Cresap Bottom and will be connected to the aluminum facilities by a high tension transmission line. The power plant will be built at a major new coal mine which will be constructed, owned and operated by the Pittsburgh Consolidated Coal Co.



Artist's conception shows Olin Mathieson's primary aluminum facility. From left to right: power plant, alumina plant, reduction plant (long building at upper center), and rolling mill. Coal mine and carbonization plant are not shown.

Power Plant

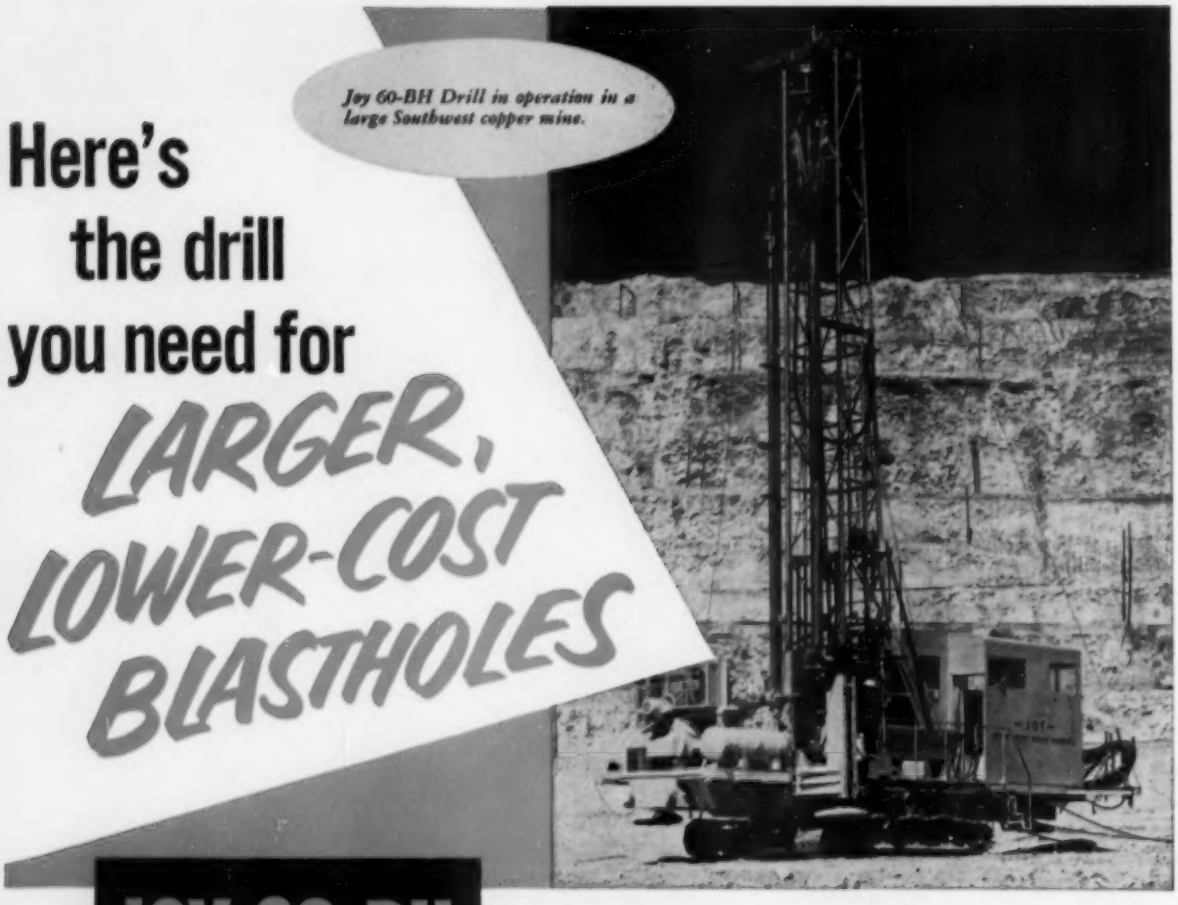
The power plant will consist of two 225,000 kw units. One unit will be owned by the Ohio Power Co., a

(Continued on page 123)

THE MOUNTAINEER: World's largest shovel, built by Marion Power Shovel Co., is now undergoing tests.

URANIUM OPEN PIT OPERATION: Coal isn't the only fuel being strip mined, as witness this operation south of Riverton, Wyo. Shovel at uranium property of Cheyenne Mining & Uranium Co. is working against 40-ft face of sandstone and limestone overburden.

Here's the drill you need for LARGER, LOWER-COST BLASTHOLES



Joy 60-BH Drill in operation in a large Southwest copper mine.

the JOY 60-BH Super Heavyweight Champion

For high-production open pit mining of copper, as illustrated above, large-diameter blastholes are a *must!* The way to drill those large-diameter holes economically—either in copper ore, or in any other open-pit mining or overburden removal job—is with the Joy 60-BH Super Heavyweight Champion. Here's why: because this Joy rotary drill excels in all three of the features which determine bit penetration:

ROTATION—Infinite variation of bit speeds, accurately controlled bit speeds, more power on bit rotation, and constant indication of bit speed and pressure by gauges.

BIT WEIGHT—The Joy hydraulic feed, using two 5-foot hydraulic cylinders, is the most efficient and dependable method of applying bit pressure. It is more accurately controlled and less hazardous than other methods.

CUTTINGS REMOVAL—Only Joy uses a heavy-duty, industrial-type, water-cooled air compressor to insure more dependable air supply required for efficient rotary-air blast drilling.

Other features include a self-aligning hydraulic automatic chuck, hydraulically raised and lowered derrick, and rod handling device.

The 60-BH, capable of drilling 9" to 12" diameter holes in even the hardest rock formations, is the largest in the outstanding line of Joy Champion "rotary-air blast" drills. Smaller models are the 58-BH Heavyweight for 7⅞" diameter holes, and the 56-BH Middleweight for 6¼" diameter holes. Let us quote on *your* requirements. *Joy Manufacturing Company, Oliver Building, Pittsburgh 22, Pa.* In Canada: *Joy Manufacturing Company (Canada) Limited, Galt, Ontario.*

Write for FREE Bulletin 35-7

Consult a Joy Engineer

For AIR COMPRESSORS, ROCK DRILLS, CORE DRILLS, HOISTS and SLUSHERS, MINE FANS and BLOWERS

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JOY

WORLD'S LARGEST BUILDER OF CORE DRILLS, ROTARY BLAST HOLE DRILLS AND MOTORIZED DRILL RIGS

Olin Mathieson Enters The Aluminum Industry

(Continued from page 121)

subsidiary of the American Gas & Electric Co.; the other by a joint subsidiary of Olin Mathieson Chemical Corp. and Pittsburgh Consolidation Coal Co. Both power units will be operated by the Ohio Power Co. and integrated into the American Gas & Electric Co. system. The plant will be designed for development to 1350 million kw capacity.

The Pennsylvania Railroad is extending its tracks at a cost of several million dollars in order to service the site at Omal, Ohio, near Clarington, Ohio.

This location will take advantage of the vast coal resources of West Virginia. The nation's coal resources are estimated to be over 2,000 billion tons and a substantial share of these resources are located in the states adjoining the Upper Ohio River. The coal reserves within the area of the Olin Mathieson operations have been estimated at more than 300 million tons. The initial requirements of coal per annum are about 2 million tons, and reserves are adequate for expanded operations in the future.

Olin Mathieson emphasized in its announcement that Governor Frank J. Lausche of Ohio and Governor William C. Marland of West Virginia have given full cooperation in working out the many details of arrangements with state and local authorities. The plants are being built under certificates of necessity from the U. S. Government, issued in order to help increase the supply of primary aluminum.

The alumina plant will have a capacity of 230,000 tons per year. The capacity of the aluminum plant will be 60,000 tons per year. At first, only about 115,000 tons of alumina will be required for the aluminum plant and the other 115,000 tons of surplus alumina will be available to the market. Most of the 60,000 tons of finished aluminum will be consumed by the Metals Div. of Olin Mathieson. However, in view of the need for flexibility, the corporation will be both a buyer and a seller of prime aluminum in order to keep the fabricating facilities in balanced supply.

Site Selection

The selection of the two sites came after a search of many months, and after dozens of locations had been carefully studied. The following factors resulted in the choice of the Ohio and West Virginia sites:

1. A desirable site adjacent to large high quality coal deposits which make possible an almost unlimited supply of economical electric power.
2. Proximity to the center of the aluminum buying market.
3. Location on deep water transportation.
4. Accessibility by rail from east coast ports.
5. Easy shipment of alumina and aluminum out of the area as well as receipt of bauxite to the plant site either by rail or water.
6. Sufficient acreage on the two sites for substantial expansion in the future.
7. Availability of electric power by a major utility system of proven efficiency.

Bauxite, the major raw material required, will be shipped to the U. S. from Surinam (Dutch Guiana). Olin Mathieson has signed a long-term supply contract for its initial requirements. First shipments for stockpiling of the raw material are scheduled for arrival early in 1957.

The formula for making aluminum is sometimes quoted as "four, two, one." This means 4 lb of bauxite for 2 lb of alumina, from which 1 lb of aluminum is produced by about 9 kwhr of dc electricity.

. . . for Low Cost Feeding of Bulk Materials At Controlled Rates

SYNTRON

"Vibra-Flow"

VIBRATORY FEEDERS

With Syntron Vibratory Feeders there is finger-tip control—electromagnetic operation—uniform feeding—plus the assurance of efficient, controllable, low cost handling of most bulk materials from course, heavy lumps to fine powders. Handle up to hundreds of tons per hour on continuous schedules with little or no maintenance.

For Proven, Quality Equipment . . .

SHAFT SEALS

Self-lubricating mechanical seals for rotating shafts. Corrosion resistant.

FEEDER MACHINES

Provide quick, accurate sizing of test samples.

SELENIUM RECTIFIERS

Vacuum process, high quality, uniform. Sizes 1" to 12" x 16".

Write today for complete catalogue data—Free

SYNTRON COMPANY

554 Lexington Ave. Homer City, Penna.

Here's a NEW Vibrating Profitable Production of

Every design and construction feature of the new Model "S" screen has been carefully calculated to provide outstanding performance at **lowest possible cost.**

Model "S"

screen handles feed up to 4 inches (coal up to 6 inches)

Need Help?

Not getting enough production? Production unbalanced? Too much waste? Regardless of your problem, you can get as much technical help as you *want or need* from Allis-Chalmers . . . a company with over a half century of experience in designing, building and applying reduction and classifying equipment for your industry.

Close Spacing of clamping bar bolts and proper camber provide added screen cloth life.

Vertical Angles add rigidity to side plates.

Replaceable full length buffer strips prevent metal-to-metal contact. Cushioning effect materially increases cloth life.

Self-locating Clamping Bar assembly holds cloth in position . . . accommodates cloth of any thickness. Full length support for hook strip simplifies installation of cloth.

NEW BULLETIN

tells how to select type and size of vibrating screen.

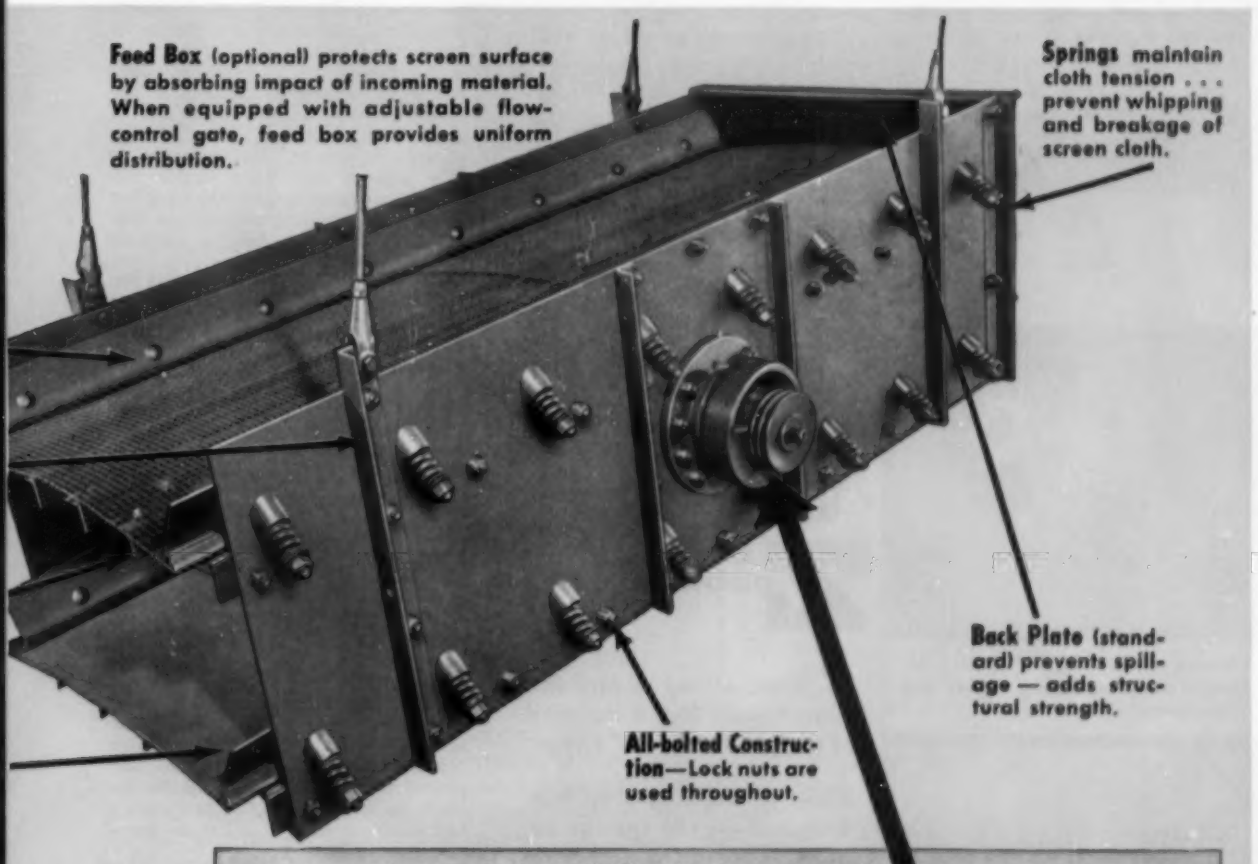
In addition to complete description of the Model "S" screen, Bulletin 07B8229 gives you an easy-to-understand procedure for selecting a screen. Get your copy from your nearby Allis-Chalmers representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin.

Sturdy Frame

1. Diagonal braces
2. Heavy channels
3. Replaceable cross members

ALLIS-

Screen . . . for Specification Aggregates


Feed Box (optional) protects screen surface by absorbing impact of incoming material. When equipped with adjustable flow-control gate, feed box provides uniform distribution.
Springs maintain cloth tension . . . prevent whipping and breakage of screen cloth.
Back Plate (standard) prevents spillage — adds structural strength.
All-bolted Construction—Lock nuts are used throughout.

Simplified Mechanism

- **Eccentric shaft** is enlarged and offset between bearings to provide major portion of throw. Distribution of off-center weight on both sides of bearing reduces shaft deflection and increases bearing life by equalizing bearing load.
- **Small counterweighted wheels** afford proper throw for screen surface selected.
- **Safe, sure method of lubrication** forces new grease into center of bearings, old grease out through labyrinth seals.
- **True running drive** extends belt life. Because the screen sheave is eccentric bored, the drive runs true . . . destructive whipping is prevented.

A-4916

CHALMERS

A-C ALLIS-CHALMERS

Uranium Extraction Now Large User of Ion Exchange Material
Latest Installation is in Canada

By all odds, the largest use of ion exchange materials outside the field of water treatment is in the recovery or extraction of uranium ores from acid leach solutions. This was the estimate given by Henry W. Foulds, president of The Permutit Co., at the time of the start of capacity production at Gunnar Mines Ltd., at Uranium City, Saskatchewan.

To date, Gunnar has spent close to $19 million in order to build its mill, carve out a townsite, and prepare the pitchblende deposit for open pit mining operations. For security reasons, actual production figures for Gunnar have not been disclosed. It is known that the mill will be processing, crushing, and leaching at least 1300 tons of ore at the outset, and the facility has a capacity of 1750 tpd. Ion exchange will be used to recover the uranium from acid leach solutions in the Gunnar flowsheet.

This mine will go a long way in making Canada the world's second largest producer of uranium, supplanting the U. S. in that position. The Belgian Congo is the largest single source of uranium.

Use of Ion Exchange Grows

Since its inception a few years ago, there are now more than 20 installations throughout the world producing uranium oxide on an impressive scale through ion exchange. Additional plants are now being designed and built.

The largest of these installations has 45 ion exchange columns in operation and is believed that few, if any, water treating ion exchange plants are larger. Development of this process has been rapid, followed by urgent large scale adaption by uranium milling interests in several localities in Africa, Canada, U. S. and Australia.

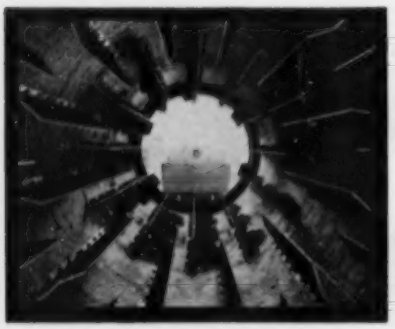
The early development of the ion exchange process was carried out under AEC contract at Oak Ridge, Battelle Memorial Institute, and the MIT metallurgical laboratory in 1949 and 1950. By February of 1951 the authorities of the South African government, together with authorities of the AEC decided to adapt ion exchange as the method of recovering uranium from gold slimes.

In September of 1952, the first ion exchange installation of exchange equipment consisting of 12 columns was placed in operation at the West Rand Consolidated Mines in South Africa. The leaching, filtration, precipitation and other handling equipment of this plant was fabricated of acid-resistant materials in contrast to the non-acid resisting construction of the adjacent gold plants. The speed with which these tremendous plans were designed, installed and placed in operation is a tribute indeed to the engineering proficiency and business skill of all those associated with these projects.

Most of the equipment used in uranium recovery is designed for automatic operation. The ion exchange columns are, for the most part, 7 or 8 ft diam and 12 ft or more high with about 5-ft deep beds.

Elution in columns is generally conducted by employing a "split" elution technique in which the tail end of the solution effluent which contains uranium plus excess eluent is recycled in the next run as the first portion of elution influent.

Another method of using ion exchange for uranium recovery is the application directly to the leach pulp without prior classification. This is the resin-in-pulp process in which large mesh resins absorb the uranyl sulfate ions. Other methods of resin-in-pulp processing are under development.



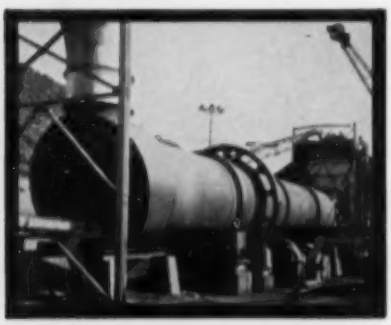
Interior of shell of "XH" Ruggles-Coles Dryer showing lifting flights and "knock-out" chains.

from **A**lumina ores to **Z**ircon concentrates

... in the drying of ores and concentrates. That is the story of Ruggles-Coles "XH" Dryers.

Small or large, each dryer is designed for the specific requirements of the user with the knowledge and experience gained from hundreds of installations.

Complete specifications upon request. Ruggles-Coles Dryers are described in Bulletin AH-438-2.



10′ diameter, 80′ long "XH" Ruggles-Coles Dryer drying bauxite.

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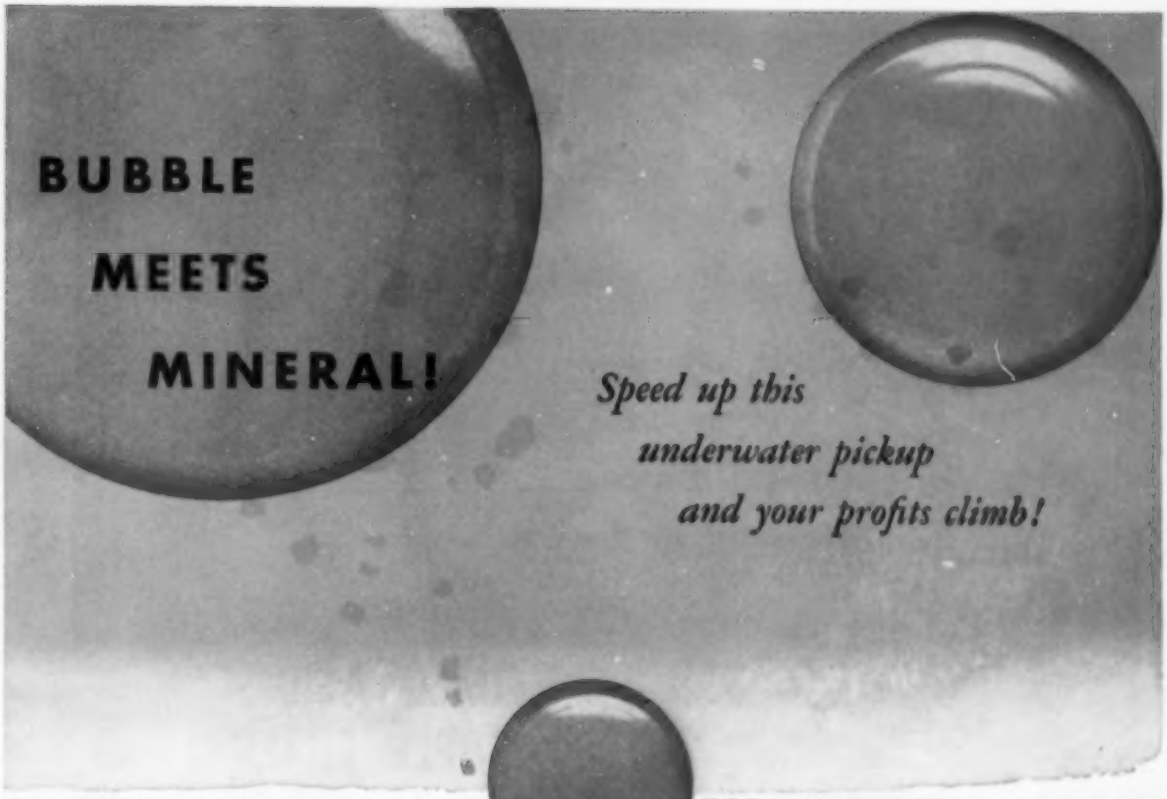

Armour flotation reagents compel the fastest attachments known —selectively float higher concentrations in less time for as little as 7¢ per ton!

The coating reaction between an Armour flotation reagent and the *specific* mineral you want is instantaneous. The Armour-treated minerals then attach quickly and firmly to rising air bubbles. As a result, you achieve a higher percentage of mineral recovery—along with increased throughput. You use less equipment, too, because the sharp selectivity of Armour cationic flotation reagents enables you to recover minerals without using an extra cleaner flotation step. And you can float the minerals from one ton of ore for as little as 7¢!

Armour produces a wide range of both cationic and anionic flotation reagents. For information and samples, send the coupon at right. Or write us, if you have a specific separation problem. Whether you want to float your minerals to concentrate them or reject them, we can suggest an Armour flotation reagent which will float more of the exact minerals you want *one by one*—in less time and at less cost.

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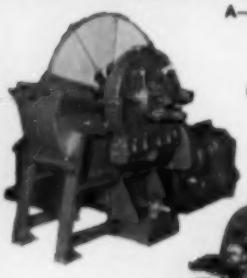
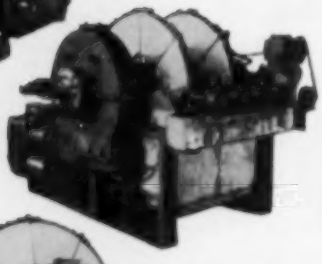
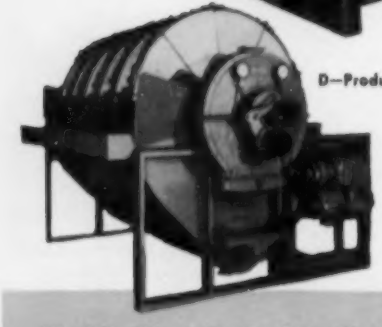
A—Platform Type



B—Test Model Agidisc



C—Special Disc



D—Production Size Agidisc

EIMCO AGIDISC SUPER FILTER for Metallurgical Slurries

Eimco Agidisc filters are, by far, the most popular filters in Metallurgical operations today.

There's a reason—that justifies this preference! Agidisc filters do a better job for less money.

Here are some of the advantages:

1. **Agidisc Filters give a clean cake discharge.**
2. **They eliminate messy "build-up" of cake on bag clamps.**
3. **Eimco Agidisc Filters provide an even distribution of evenly dispersed grain size material over the entire disc surface. This uniformity in thickness provides for greater tonnage, better drying and faster dewatering.**

Numerous installations on dewatering of Metallurgical concentrates show Eimco Agidiscs improve tonnage capacity by as much as 22% and give an overall reduction of moisture content in cake by as much as 2% as compared with ordinary filters.

Let us show you an Eimco Agidisc in operation.

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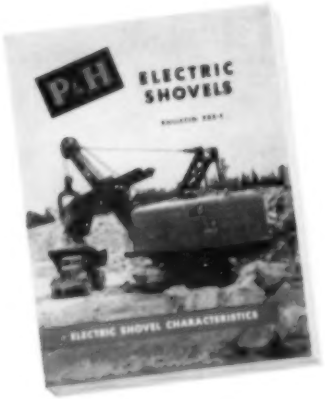
You Can't Beat An Eimco!

Why is P&H *at the head of the Big Three?*

MAGNETORQUE* and ELECTRONIC CONTROLS give operators the only modern electric shovels



For a clearly illustrated description of Magnetorque* and how it sets a new standard for electric shovel design and operation, write for Bulletin X-156. Other booklets available on electric shovel models from 3 to 10 cu. yd. capacity. A copy of these publications will be sent those who request it on their company letterhead.

These revolutionary advances in design and performance of electric shovels are just two of the reasons why operators and owners are pointing to P & H for their outstanding achievement in electric shovels . . . why P & H now is at the head of the Big Three . . . why P & H can promise you the only modern electric shovel.

Just think! Power transmission *without friction's* in massive electric shovels. Boosts efficiency. Cuts maintenance and operating costs. *This is Magnetorque.* Exclusive with P & H.

Just think! Complete control of dig, hoist, swing and propel of these giants with simple stepless control. 12% faster cycles; 16% savings in operating time. *This is Electronic Control.* Exclusive with P & H.

For complete information, call your P & H representative. Electric Shovel Division, Harnischfeger Corporation, Milwaukee 46, Wisconsin.

*T. M. of Harnischfeger Corp. for Electro Magnetic Type Coupling

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P&H ELECTRIC SHOVEL DIVISION

New Tools for the Metallurgist from Cyanamid Research

Research to develop new reagents and improved application methods goes forward unceasingly at Cyanamid's Stamford Research Laboratories. Today, emphasis is upon more efficient treatment techniques for tomorrow's lower grade ores. With a 40-year background in mining chemicals and first-hand knowledge of mill problems derived from its highly-trained field engineers, Cyanamid is particularly well equipped to undertake this important research. From such research come new, more efficient Cyanamid products and processes for treating the leaner, more refractory ores in the competitive days ahead.

1. Valuable reference for reagent researchers is a Molecular Formula Index of over 32,000 compounds that have been synthesized or tested by Cyanamid. This vast compilation of basic data gives our reagent researchers access to the findings of all Cyanamid research in every chemical field.

2. New chemical compounds are synthesized for testing in minerals beneficiation by the Mineral Dressing Laboratory.

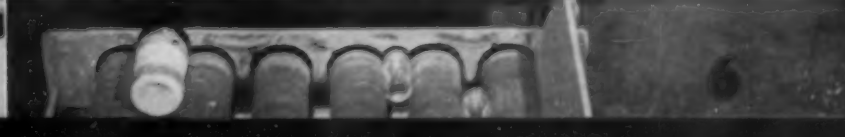
3. & 4. New flotation reagents are given a thorough evaluation by Cyanamid flotation engineers.

5. Highly-trained microscopists are available for examination of minerals and test products.

6. New cyanidation techniques are investigated with testing carried out in bottles on rotating rolls to simulate the agitation of pulp in a cyanide plant.

7. Facilities are available for gold and silver determinations by fire assaying, together with the most modern methods and equipment for conducting chemical analyses.

8. Settling tests with improved AEROFLOC® Reagents are carried out with stirring mechanism to simulate action of thickener rakes.



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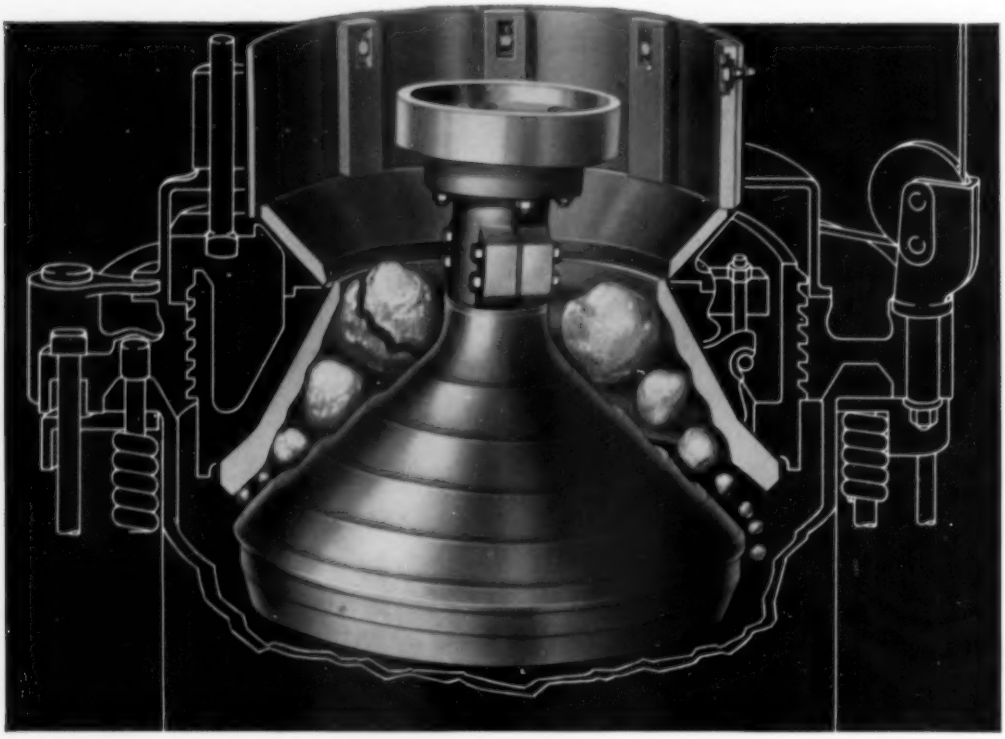
MINERAL DRESSING DEPARTMENT 30 ROCKEFELLER PLAZA, NEW YORK 20, N.Y.

CYANAMID

AMSCO® CRUSHER PARTS

"give" a little to TAKE MORE PUNISHMENT



Amsco crusher parts are made of the toughest steel known—manganese steel. Typical of the Amsco line are the mantle and bowl liner in this sketch of a Symons® Cone Crusher. Symons is a registered trademark of Nordberg Manufacturing Company.

Under the violent crushing forces of impact, abrasion and pressure, the surface of Amsco manganese steel crusher parts work-hardens to as high as 500 Brinell. Yet beneath the working surface, the metal remains strong and ductile . . . able to *give* slightly under crushing forces . . . developing hardness as a new working surface is exposed by wear. That's why manganese steel crusher parts last so long, enduring severe abuse and resisting cracking or chipping even when worn thin.

Amsco makes manganese steel crusher parts for most manufacturers of crushing, grinding and pulverizing equipment. Buy your replacement parts from your crusher manufacturer to be sure of getting Amsco manganese steel.

Amsco also produces other alloy steels with maximum wear resistance under particular service conditions.

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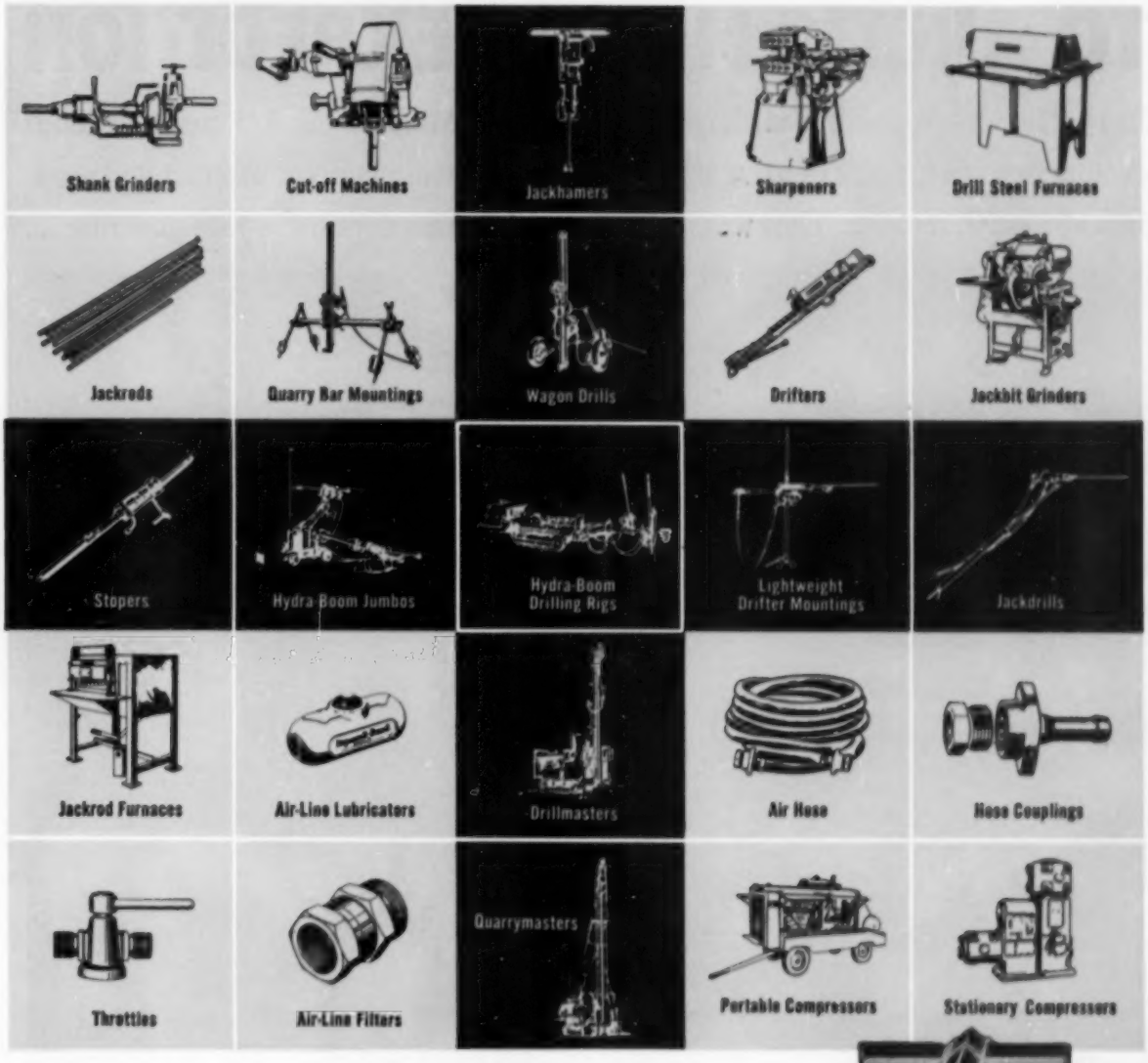

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ROCK DRILLS • COMPRESSORS • AIR TOOLS • TURBO BLOWERS CONDENSERS • PUMPS • OIL & GAS ENGINES

ATLAS COPCO EQUIPMENT SENT TO ARCTIC MINING EXPEDITION

In 1952, an enterprising Danish company, Nordisk Mineselskab A/S, began arduous exploratory work and extensive trial drilling in the mountainous, uninhabited arctic area of East Greenland. They were after supposedly rich deposits of lead and zinc . . .

The ship bringing one of the first prospecting teams in the ice off Greenland.

6,500 FEET OF TEST TUNNELS

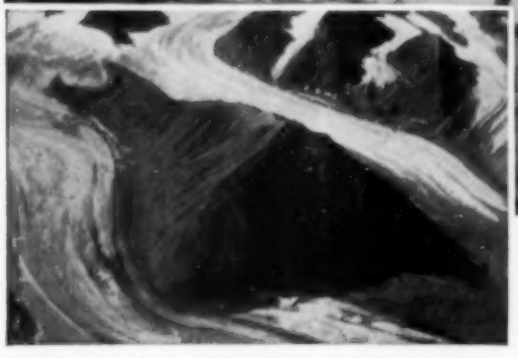
From the Danish company in the Atlas Copco Group, C. K. Alling A/S, came Atlas Copco rock drills and Sandvik Coromant tungsten-carbide-tipped drill steels to King Oscar's fjord—the site of the mining expedition. Whether these deposits of minerals existed in any worthwhile quantity could now be determined and the equipment was set to work drilling numerous test tunnels—totalling 6,500 feet in length. The results were good. So good, that large-scale mining will start shortly and the first consignments are expected to reach Denmark in about two years time.

MILL INSIDE MOUNTAIN

An unusual feature of this project is the location of the mill for the extraction of the ore. Due to Greenland's arctic temperatures, this will be situated inside the mountain in which mining will take place.

Experts estimate that the mine will yield an annual production of 70-80,000 tons of ore, giving 10,000 tons of lead concentrate and the same quantity of zinc blend concentrate.

Commencing one of the test tunnels with Atlas Copco drills and Sandvik Coromant integral steels. Together they make an unbeatable combination.



An aerial view showing the rough nature of the areas of East Greenland where the mining development is taking place.

DRILLS, STEELS, AND A METHOD

The choice of Atlas Copco rock drills and Coromant drill steels to carry out the drilling tests—and possibly later to work the deposits also—was influenced by the impressive performances they have put up in mines and on construction projects throughout the world.

These drills and steels have been developed closely together to an unbeatable drilling unit. It is a method enabling more drills at the face, smaller crews, faster drilling and economies all round. It is the method that helps beat ever-rising post-war production costs on Kalgoorlie's Golden Mile in Australia. Now, it is opening up a hidden mineral wealth in Greenland.

Supplying air under tough conditions are Atlas Copco stationary and portable compressors and the mucking operations are performed with Atlas Copco loaders.

The Atlas Copco Group puts compressed air to work for the world. It embraces thirty-one Atlas Copco companies and twenty-four agents, manufacturing or selling and servicing Atlas Copco equipment in more than 50 countries throughout the world.

MAIL THIS COUPON to the most convenient of the addresses given here:
U.S.A., Atlas Copco Pacific, Inc., 930, Brittan Avenue, San Carlos, California; Atlas Copco Eastern, Inc., P.O. Box 2568, Paterson 2, N.J.; CANADA, Atlas Copco Canada, Ltd., Montreal, A.M.F., P.Q.; MEXICO, Atlas Copco Mexicana S.A. Apartado Postal 56, Torreon, Coahuila.
UNITED KINGDOM, Atlas Copco (Great Britain) Ltd., Wembley, Middx.; FRANCE, Atlas Copco France S.A., 29, Rue Marbeuf, Paris 8e; HOLLAND, Atlas Copco Holland N.V., P.O. Box 6056, Rotterdam; ITALY, Atlas Copco Italia, S.p.A., Viale Marche 15, Milan.
AUSTRALIA, Australian Atlas Copco Pty. Ltd., P.O. 54, Auburn, N.S.W.; SOUTH AFRICA, Delfos & Atlas Copco (Pty.) Ltd., P.O. Box 504, Benoni, Transvaal.
Readers in countries outside those listed above and who do not know the name of their local Atlas Copco company or agent, please write to Atlas Copco AB, Stockholm 1, Sweden.

Please forward details of ***Atlas Copco Rock Drills and Sandvik Coromant Drill Steels.***

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* I am also interested in other Atlas Copco equipment (*please state which below*).

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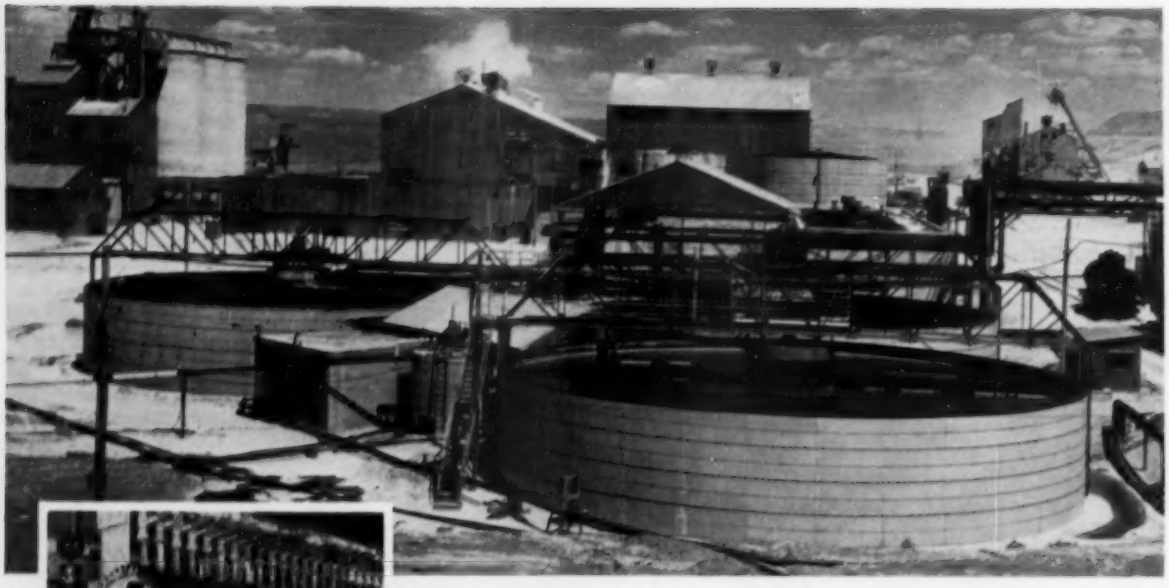
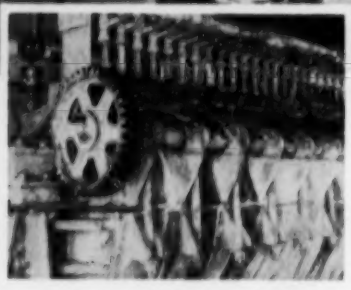
* *Manufacturers of Stationary and Portable Compressors, Rock-Drilling Equipment, Loaders, Pneumatic Tools and Paint-Spraying Equipment*

THE ATLAS COPCO GROUP OF COMPANIES



General view of plant with three Dorr Thickeners in foreground.



Closeup of one of the six Sweetland Filters.

Dorr-Oliver Techniques

at INTERMOUNTAIN CHEMICAL COMPANY

(OPERATED BY WESTVACO CHLOR-ALKALI DIVISION, FOOD MACHINERY & CHEMICAL CORPORATION)

The vast trona deposits throughout the Green River, Wyoming, area represent an assured supply of soda ash for expanding western industry. But before calcination, insolubles amounting to approximately 10% must be removed by physical means. And here Dorr-Oliver equipment and methods play a vital role.

At Intermountain Chemical Company's Green River Processing Plant, trona ore is crushed, screened and dissolved in mother liquor and a small amount of makeup water. Solution is then clarified in two 80′ dia. Dorr Thickeners. Underflows are washed free of entrained salt in a third Dorr Thickener. Combined overflow from the three Thickeners is a sodium sesqui-carbonate solution which is polished on six #12 Sweetland Filters. The Sweetlands are of cast iron construction with 72 leaves each providing a total filter area of 6024 square feet. After polishing, the solution is concentrated in triple effect vacuum crystallizers. The resulting crystals are thickened in two 30′ dia. Dorr Units and are then calcined to soda ash. Operated by Westvaco Chlor-Alkali Division of Food Machinery and Chemical Corporation, the plant has a capacity of 350,000 tons per year.

For the Process Industries, Dorr-Oliver offers a complete and integrated service. Well-designed equipment, as installed at Intermountain Chemical, is an important part of this service. But if your processing needs involve laboratory and pilot plant testing, flowsheet preparation, economic analysis or complete plant design and construction, we can also be of help. For a complete picture of the scope of the Dorr-Oliver technical service write for a copy of Bulletin No. 7003. Dorr-Oliver Inc., Stamford, Connecticut.

Sweetland — T.M. Reg. U. S. Patent Office

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Simplicity OS-A-VEYOR feeders lower maintenance and increase operating efficiency . . . LIMESTONE to TACONITE ORE

These Simplicity vibrating pan type feeders have proven themselves throughout the mining and quarry industry. They are not only handling various types of stone and aggregate, but the extremely abrasive taconite ore.

Lower maintenance costs have been proven by long experience in the field. The simplicity of the pan construction allows the unit to be easily repaired with existing materials. These feeders are available with replaceable liners of abrasion resistant steel. The oscillating action is provided by two eccentric shafts coupled to a single V-belt drive . . . leaving only one assembly and four bearings to lubricate.

The Simplicity Os-A-Veyor feeders are self-cleaning units. They experience none of the return spillage found in apron feeders. The Os-A-Veyor feeder will discharge material with a minimum fall, the height of drop is not determined by the size of a sprocket. The units are designed to handle heavy column loads. Overloading the feeders causes no damage, as there is no mechanical connection between the eccentric drive and the main frame or bin.

The Simplicity Os-A-Veyor feeders are main frame supported, or can be supported from the bin with spring and cable suspension, eliminating the need for separate concrete foundation. Sizes available range from 1' x 4' to 6' x 20' with capacities to 1000 tons per hour.

169

If you wish further information on Simplicity Os-A-Veyor feeders, grizzly feeders, horizontal screens or gyrating screens write . .

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IN 1955 mineral production in the U. S. jumped 11 pct to a new high of $15.8 billion, according to a U. S. Bureau of Mines summary. Previous high of $14.4 billion was recorded in 1953. Total for 1954 was $14.1 billion. Nearly all commodities registered higher values in 1955, with metals showing the largest increase—35 pct—and fuels and nonmetallic minerals each increasing more than 8 pct. Major cause of the upswing was substantial expansion in production of liquid and gaseous fuels, bituminous coal, copper, and iron ore, in that order. Zinc, lead, manganese ores, and tungsten also recorded large value increases.

Aluminum. Primary aluminum output reached a new high with an estimated 1.56 million tons. This was an increase of 100,000 tons over 1954. The USBM also stated the demand was so great that of 400,000 tons of metal scheduled for delivery to national stockpile during 1955, only 125,000 tons was acquired. R. S. Reynolds, Jr., president, Reynolds Metal Co., said that aluminum shipments to U. S. industry during 1955 had been about 35 pct higher than in 1954. Ten years ago the automobile industry used less than 10 lb per car. One of the latest models uses 197 lb per car, including a gold-anodized aluminum grille. The electrical field is using an aluminum strip, which is self-insulating as the result of a special anodizing treatment. Prediction: more aluminum use in 1956 than ever before.

Coal. The bituminous coal and lignite industries, according to the USBM, reversed a two-year downward trend as estimated output exceeded 1954's by nearly 19 pct. Anthracite production continued to decline in 1955, dropping 8 pct. Tom Pickett, executive vice president, National Coal Assn., said that 1954 coal output was the lowest since 1938 and that 1955 production was still substantially below the amount necessary to maintain the industry at a level of readiness in event of full mobilization. "The 1955 figure is also substantially below the ten-year average since the end of World War II of 515 million tons per year," Mr. Pickett also said. "The only fuel with known adequate reserves to meet an increased, long-range demand for energy is coal. . . . Oil and gas are limited and increasingly expensive. Atomic energy is years away from becoming a cheap or competitive source of power."

Copper. Copper reached the headlines with prices at the highest level in 90 years. The Copper & Brass Research Assn. reports that about 150,000 tons of refined copper were lost because of strikes in the U. S., Chile, and Africa. U. S. consumption of copper is around 15 lb per capita, but the world-wide figure is only 1.8 lb, excluding the U. S. As underdeveloped countries become more technically advanced their per capita consumption should rise. A rough balance between supply and demand is expected to take place some time during 1956, provided there are no major strikes in the copper industry. *If* there are no major strikes, output of refined copper for 1956 will reach a new record for the Free World—an estimated 3 million tons. Production of 1955 is estimated at 2.7 million tons, an all-time record.

Ferroalloys. In 1955 the output of alloy and stainless steel rose 45 pct as compared with a 33 pct overall increase of steel production. William C. Keeley, president, Vanadium Corp. of America, states that there is no sign of an early change in the trend. Automobile makers have set their sights high and the budgets of the appliance manufacturers for 1956 look good. "Although residential building construction may well ease moderately in 1956, the slack should easily be taken up by increases in industrial, commercial, and other types of building."

Industrial Minerals. *Rock Products* agrees with Mr. Keeley (see above) that private residential construction will ease in 1956 and forecasts a decrease of 3 pct. Farm construction will decrease 7 pct. Hospital and institutional construction will remain the same. All other construction will increase in 1956. Public services, including airports, will increase 33 pct; commercial construction 23 pct; public housing, 20 pct; religious 20 pct. It is predicted that cement output for 1956 will reach nearly 320 million bbl; 1955's was estimated at 298 million bbl. Crushed stone will reach 325 million tons in 1956. Sand and gravel—about 500 million tons in 1955—will climb to 534 million tons in 1956.

Iron Ore. USMB reports that despite record steel production in the U. S. in 1955, shipments of iron ore from mines in this country were 11 million gross tons less than the record year 1953. They were, however, 40 pct higher than in 1954. Iron ore imports swelled to 24 million tons compared with 16 million in 1954 and 11 million in 1953. Canada and Venezuela were the chief foreign sources.

Lead. Output of refined lead for 1955 is estimated by the USBM at 484,000 tons. This is 8000 tons less than in 1954. Strikes throughout July and August of last year closed certain major refineries. Domestic mine output increased to 332,000 tons, compared with 319,000 tons in 1954, but remained well below the 1946 to 1955 average of 372,000. Secondary lead recovered from lead-base and tin-base scrap is estimated at 485,000 tons in 1955, compared with 458,000 tons in 1954. Lead imports approximated the 1954 rate, pigs and bars totaling 270,000 tons, and lead in ores and concentrates totaling 155,000 tons. Consumption of primary and secondary lead is estimated at 1,185,000 tons—8 pct above 1954.

Magnesium. All domestic magnesium production in 1955, according to the USBM, was by the electrolysis of magnesium chloride obtained from sea water. Primary magnesium production was 12 pct below 1954, but consumption gained 20 pct.

Nickel. Free world nickel production in 1955 again set a record with output estimated at about 427 million lb, according to John F. Thompson, chairman, International Nickel Co. of Canada Ltd. This is an increase of approximately 40 million lb over previous high of 387 million lb in 1945 and 87 million lb over 1953 Free World production. Canadian producers accounted for some 347 million lb in 1955. Remaining Free World production was divided among Cuba, approximately 7 pct; New Caledonia, 5 pct; Japan, 3 pct; U.S., 2 pct; other countries, 2

pct. However, this was still not enough to go around and during 1955 the U.S. Government diverted to industry approximately 24 million lb of scheduled stockpile purchases. Plating concerns and manufacturers of electronic concerns have complained that nickel shortages have curtailed their operations. The scarcity of nickel supplies, Mr. Thompson said, "was further aggravated by the sustaining trend in North America toward larger areas of bright metal on passenger cars, together with the higher rate of automobile production." Nickel output in 1956 is estimated at 442 million lb, a gain of approximately 65 pct above 1949 production.

Rare metals. Domestic beryl was produced at about the same rate in 1955 as in 1954, but preliminary figures at the USBM indicate that world beryl production increased about 15 pct. Supply was more than ample. For the first time in history domestic output of columbium-tantalum mineral concentrates was significant compared with consumption due to the start of dredging an euxenite mineral in Valley County, Idaho. World production of columbium mineral concentrates increased more than 50 pct and production of tantalum concentrates gained more than 100 pct compared with 1954. USBM zirconium plant at Albany, Ore., was shut down in May and zirconium sponge production dropped about 39 pct below 1954 despite record output by private industry.

Selenium. USBM stated that there is no relief in sight for the heavy demand and short supply of selenium. In August 1955 prices jumped to $10.50 per lb from $7.25 with many consumers paying $13.00 and more. Selenium was produced from selenium scrap and from electrolytic refining of blister copper, but there was no production directly from seleniferous ores.

Silver. According to Handy & Harman, the withdrawal of the Bank of Mexico last March ended the 26-month period of stable prices on the New York market. U. S. arts and industries consumed about 100 million oz in 1955, up 18 pct from 1954. Improvement was particularly marked in electrical and electronic uses.

Steel. Admiral Ben Moreell, chairman, Jones & Laughlin Steel Corp., stated that "The all-time record production of more than 116 million tons of ingots in 1955 has strained our mills to the utmost. Even so, we have not been able to satisfy the demand. Demand in excess of available supply would ordinarily be looked upon as indicative of a prosperous condition. . . . But there are disquieting signs of trouble ahead. . . . The industry is faced with a construction bill over the next ten years of $8.5 billion for new capacity. To this should be added an additional sum of about $7.5 billion to replace existing worn-out and/or obsolete equipment." Admiral Moreell remarked further, "Although the price of steel has risen substantially in the postwar period, the rise has not been enough to place steel in a position of 'parity' with other industries."

Max D. Howell, executive vice president, American Iron and Steel Institute, stated that "with a recognition on the part of our taxing authorities of the necessity for recovering replacement cost of existing facilities out of profits—the industry will continue to meet the demands of our expanding economy."

Roger M. Blough, chairman, U.S. Steel Corp., pointed out that the 1955 steel record was "established almost entirely on a basis of civilian demand. Governmental purchases accounted, directly, for only about 2 pct of all steel shipped." Major increases in production, he added, will be needed in the Chicago area and in the Western market. The steel industry, according to Benjamin F. Fairless, president of AISI, plans for a $3 billion expansion. This year $1.2 billion will be spent and the complete program will add about 5 million tons of steel a year to the industry. This will raise capacity to about 143 million tons in three years.

Sulfur. Production of sulfur in 1955 was increased to an estimated 6.9 million LT. This was 250,000 tons more than in 1954. Domestic consumption plus exports rose 400,000 tons to an estimated 7.1 million tons, according to Langbourne M. Williams, president, Freeport Sulphur Co. Most new U. S. production came from salt dome deposits of Louisiana and Texas mined by Frasch hot water process.

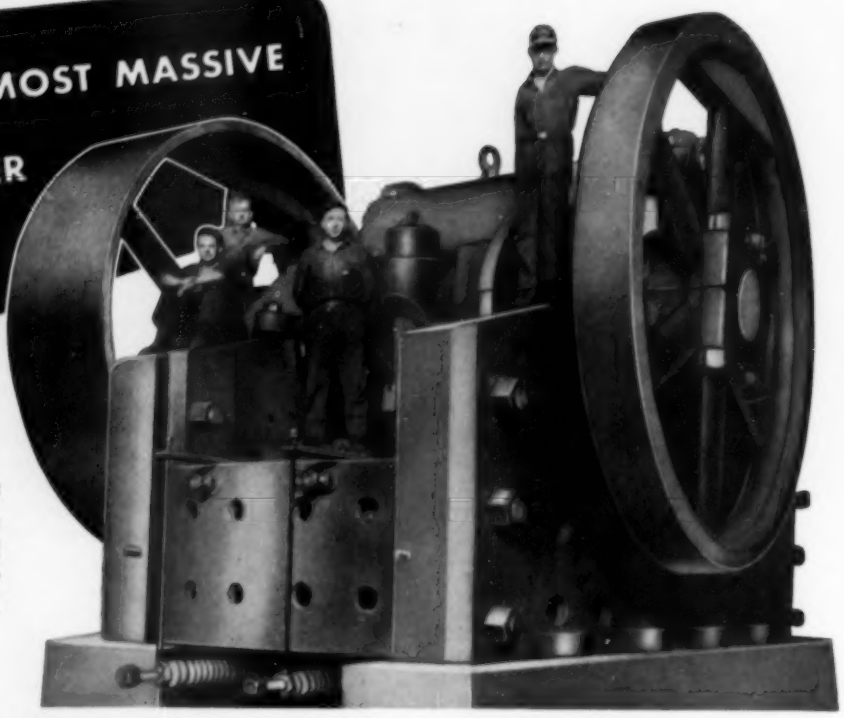
Titanium. "Current Government estimates show probable 1956 requirements for mill products ranging from 4000 to 4500 tons, thereby indicating that fabricators will be under extreme pressure to more than double their record 1955 activity," said T. W. Lippert, manager of sales and technical service, Titanium Metals Corp. of America. He estimated the value of titanium products sold this year at $60 million, with the sales of titanium sponge—the pure intermediate metal from which mill products are made—accounting for an additional $30 million.

"For 1956, dollar value of mill products will likely exceed $120 million and separate sponge may account for more than $40 million." About 90 pct of titanium is used for military aircraft.

Tungsten. USBM report stated that domestic tungsten has a record high for the second consecutive year, estimated at 15 million lb contained metal. Consumption in the U.S. approximately doubled that of 1954. USBM estimates present Government purchase program will be completed in mid-1956.

Zinc. According to the American Zinc Institute, domestic mine production will show a modest increase in 1955 over the previous year, but there is no indication of a return to the higher production levels of earlier years. Some of the increase credited to 1955 production was, in fact, zinc fume from old slag piles. Slab zinc production at domestic smelters in 1955 totaled 1,031,018 tons, 18.7 pct above 1954 and a top record. Smelter shipments totaled 1,114,316 tons or 20.5 pct more than in 1954, substantially exceeding the previous high of 996,000 tons in 1950. Shipments for domestic consumption passed the million-ton mark, up 28 pct in comparison with 1954. Exports were off about 30 pct and shipments for Government accounts were off approximately 20 pct from 1954.

STRONGEST MOST MASSIVE JAW CRUSHER BUILT



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The cost of setting up to do business has many a mining man weighing the cost against the advantages.

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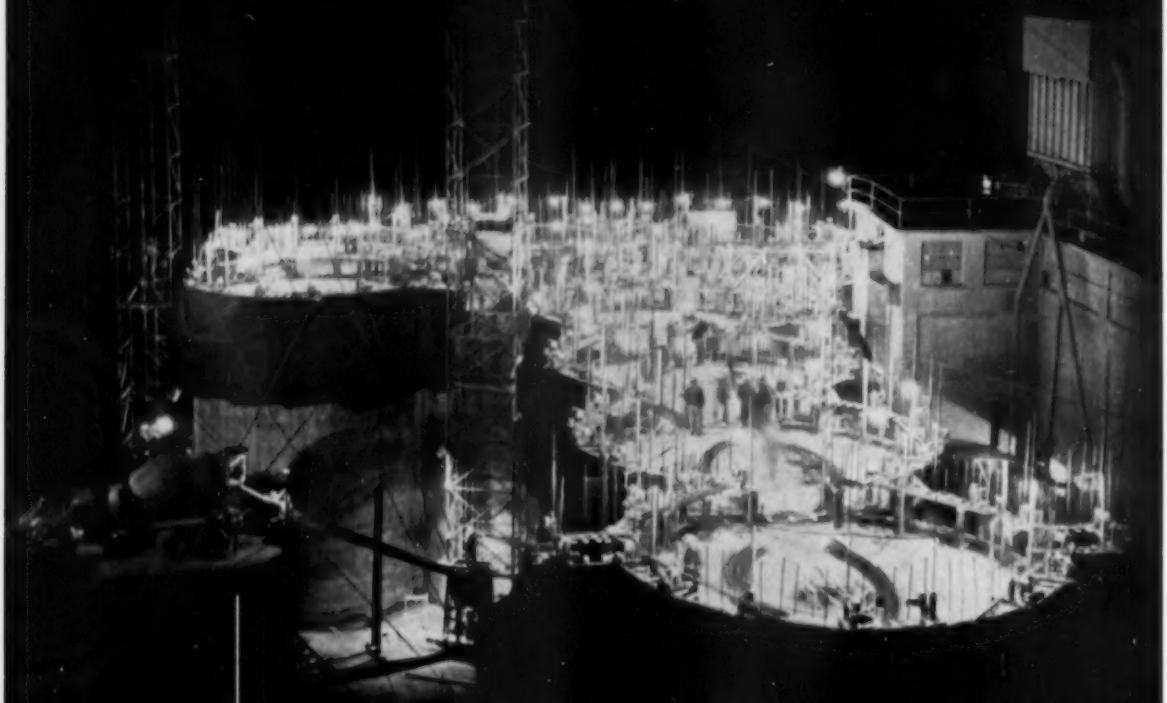

The pouring of this nine unit slip-formed concrete storage is but one current example of Stearns-Roger engineering design and construction of materials handling and storage plant facilities.

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NEW D9 TRACTOR

Moves more than 600 cubic yards of shale per hour!

This big new CAT* D9 Tractor 'dozes over 600 yds. per hour over a 100-ft. push. Its No. 9A blade handles 12 to 15 yds., trench-dozing on a 30% favorable grade. Material is shale base course for a haul road at Monsanto Chemical Co.'s Soda Springs, Idaho, phosphate mine.

Like all Cat-built equipment, the new D9s are engineered to do more work with less down time at low cost. Morrison-Knudsen Company, Inc., owns this and other giant Turbocharged 286 HP D9s here, purchased because of previous experience with Caterpillar equipment. The company also has Caterpillar D8 Tractors on this job.

The D9s are working in the phosphate beds of southern Idaho, largest known deposit in the world. The giant yellow "Kings of the Crawlers" strip overburden, which varies from 6 ft. to 10 ft. in depth, and feed ore to the shovel. These great new yellow machines are the product of many thousands of hours' testing on proving grounds and actual construction and mining jobs.

The D9 is tough and traditionally Caterpillar from its completely new, 4-cycle engine with Turbocharger to its "water quench" hardened track shoes. It's available with direct drive or torque converter for speeds to 7.8 MPH. Operators report it fast and easy to handle, with hydraulically boosted steering and brakes, "in-seat" starting, and smooth "live shaft" drive for cable controls.

It all adds up to the "workingest" tractor ever built. See your Caterpillar Dealer for details on the D9 with No. 9A or No. 9S Bulldozer blades. And count on him for fast, skilled service and Caterpillar parts you can trust.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

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NAME THE DATE... YOUR DEALER WILL DEMONSTRATE

New Headquarters to be Selected on a National Basis

The Committee of Five Presidents in its report dated Feb. 2, 1955, and amplified in its report of Apr. 4, 1955 (signed by four presidents), recommended that the new Engineering Center be located on the Schenley Park site in Pittsburgh, basing their recommendation on an offer of cash and site by a public-spirited Pittsburgh group, which resulted in the lowest estimated capital cost and annual expenditure of the four sites considered in detail, viz., Chicago, New York, Philadelphia, and Pittsburgh. The AIEE approved this recommendation, and the AIChE approved without commitment.

The Committee of Five Presidents necessarily gave major consideration to the liberality of local groups with substantial offers of cash and site. These offers received careful study on a cost basis, and meanwhile the societies developed data as to their present and future needs.

Then, on June 8, 1955, a proposal referred to as the Kelly letter,* was received by United Engineering Trustees and the five societies—AIME, ASCE, ASME, AIEE, and AIChE. This letter, signed by 21 leaders in national engineering education and industrial fields, urged the societies to choose their new headquarters on a national basis.

* The complete text of this letter appeared in MINING ENGINEERING, page 800, August 1955.

The Kelly letter went on to state: "If such a choice is made, a group of the undersigned will organize a large national committee, representing all sections, all technologies in your Societies, and a variety of industries to conduct a nationwide drive for funds." In addition, the group offered to finance the cost of a study by an independent consulting firm. The five societies decided that this study should be at the cost of the societies and formed a 15-member Special Task Committee.

Excerpts from a guidance memorandum of this committee follow:

"This Special Task Committee is charged with the duty of recommending a specific site with improvements for the Engineering Societies Center, based upon a review and comprehensive additional study of feasible locations.

"The predominant consideration throughout this work should be the long range welfare of the entire membership over the years, so that a similar committee two generations hence will agree that the site now selected was well done and their only problem will then be to plan extensions and provide for healthy growth and more effective unification and coordination of the engineering profession for the newer and enlarged services to enrich mankind in their day.

"The plans carried out by our predecessors fifty years ago have served us well, but there is urgent need for additional space which is not feasible on the present site. Let us, therefore, plan for the future with the realization that our final judges have not yet been born."

A nationally known management consulting organization, McKinsey & Co., with offices in New York, Chicago, Los Angeles, San Francisco, and Washington, D. C. has been selected. This organization will serve as staff for the Special Task Committee.

The committee has requested the Boards and Councils of the Societies to extend the deadline for its report to May 1, 1956 and has asked the Pittsburgh Engineering Trust to extend its generous offer of site and cash to Oct. 1, 1956.

H. DeWitt Smith

CREDIT WHERE CREDIT IS DUE: The Annual Review issue is a cooperative project. Primary credit goes to the eight authors who compiled major articles, and to the individuals credited with sections of these articles. But, on behalf of these authors and of the Mining Branch as a whole, we wish to extend a word of appreciation to the hundreds of others whose contributions are not specifically acknowledged—to those who supplied a picture, a fact, a paragraph, or a page. It is this cooperation that makes the review issue possible each year.

—The Editors

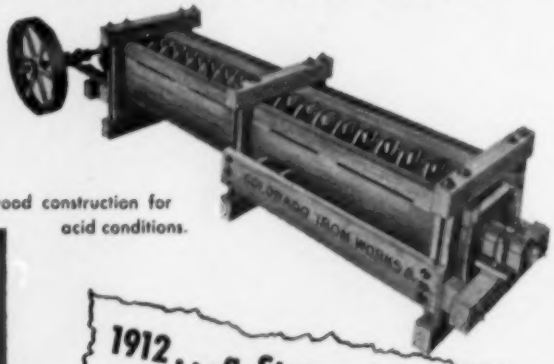
AKINS 1st in EXPERIENCE

on efficient, low-cost classification

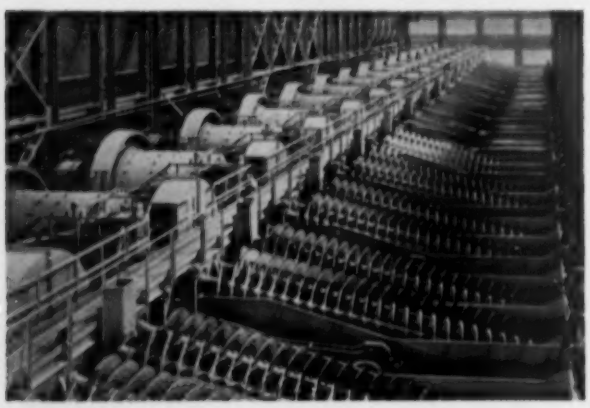
1908... the first Akins. Colorado Iron Works Company, established in 1860, specialized in making crushing, grinding, screening, cyanidation, amalgamation and smelting equipment. The Akins Classifier was developed by CIW to provide a practical, continuous system for separation of sand from slime.

The outstanding success of the Akins led to many other profitable applications and to Akins leadership in the field of classification. Today, every Akins installation on classification, sand washing, and heavy media is backed by 48 years of specialized classifier experience, 96 years experience in the mining machinery business.

1908... first Akins was for SHANNON COPPER CO., Clifton, Arizona



Photos show typical early models of the Akins, including one of wood construction for acid conditions.



1956 Photo shows part of present installation in large copper company operation... within a few miles of the same location where the first Akins was used by Shannon Copper Co. This company, since 1918, has used a total of 116 Akins Classifiers and 114 Marcy Mills in its various plants.

1912... a Statement of Policy ...Then as now

"Our aim has always been the production of a high-grade line of machinery, the prices being made as low as consistent with high quality. In no case do we attempt to build a machine to come within a certain price and place it in the field of competition with others having low first cost as their chief merit. It is this policy, consistently maintained for fifty years, that has established our enviable reputation."

(taken from CIW catalog No. 10C published in 1912)

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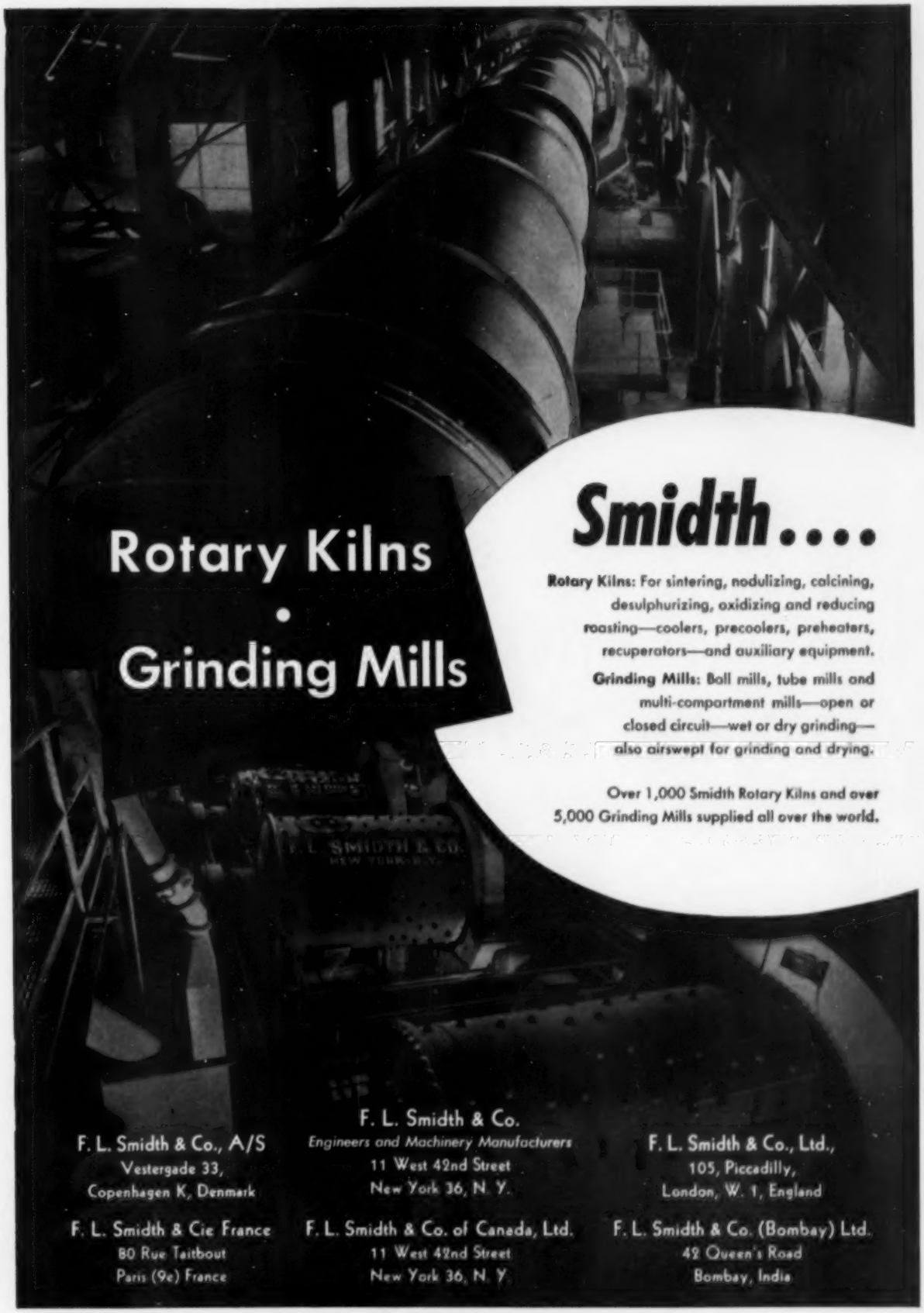

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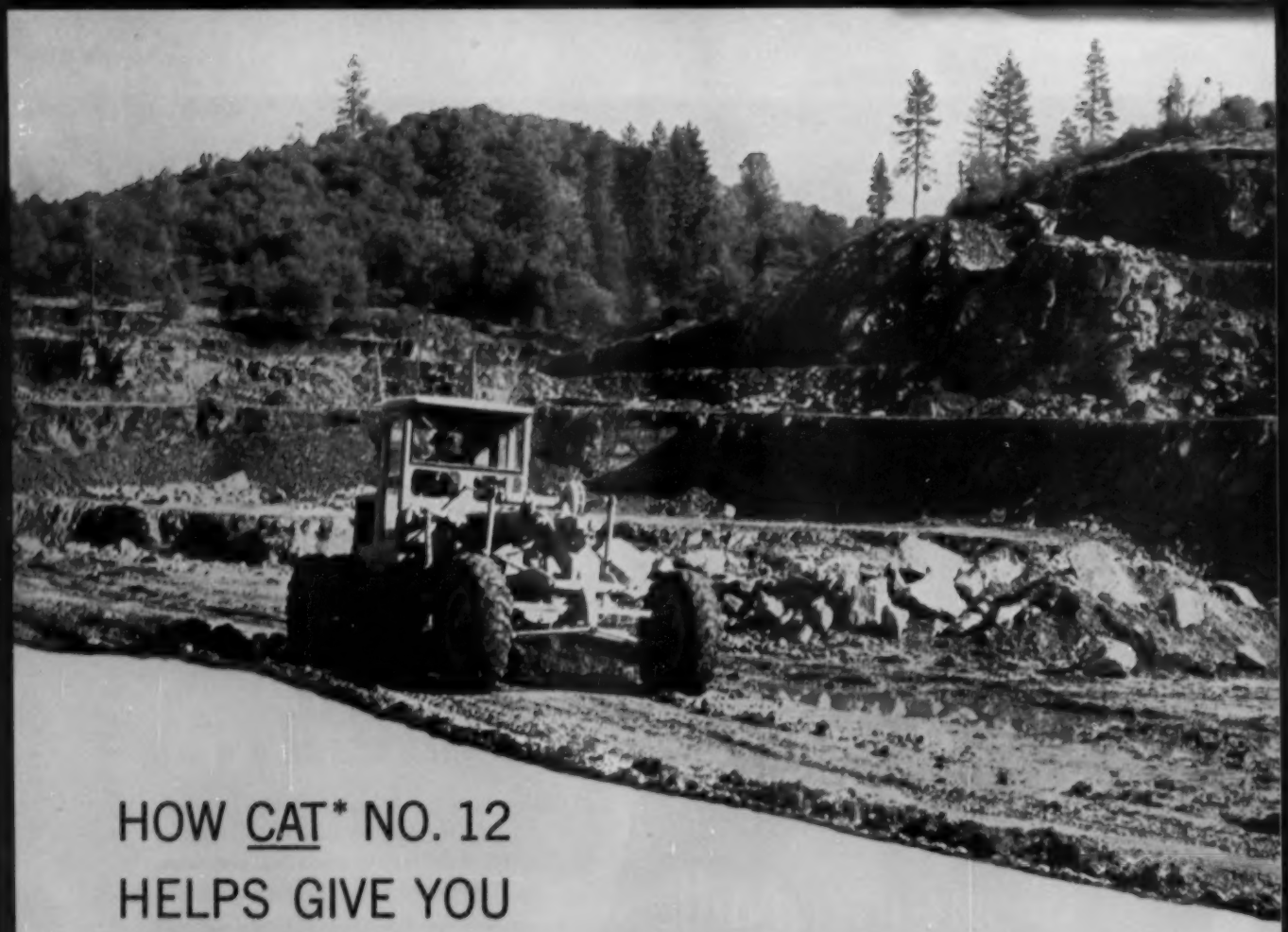

HOW CAT* NO. 12 HELPS GIVE YOU "LOWER COST PER TON"

OUT IN San Andreas, Calif., this Caterpillar No. 12 Motor Grader works eight hours a day, five days a week, the year around. It maintains haul roads and plant roads around the limestone quarry of Calaveras Cement Co. Plant manager Grant W. Metzger says, "We like the dependability of the machine and its ease of maintenance. Cat equipment gives us lower cost per ton."

Like all Caterpillar Motor Graders, the No. 12 is a balanced unit, built—not merely assembled—by a single manufacturer. Engine, blade capacity and working speed are carefully matched for maximum efficiency.

In addition to traditional Caterpillar ruggedness and freedom from down time, the No. 12 now has important new features for even higher production at lower cost on *your* operation:

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Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

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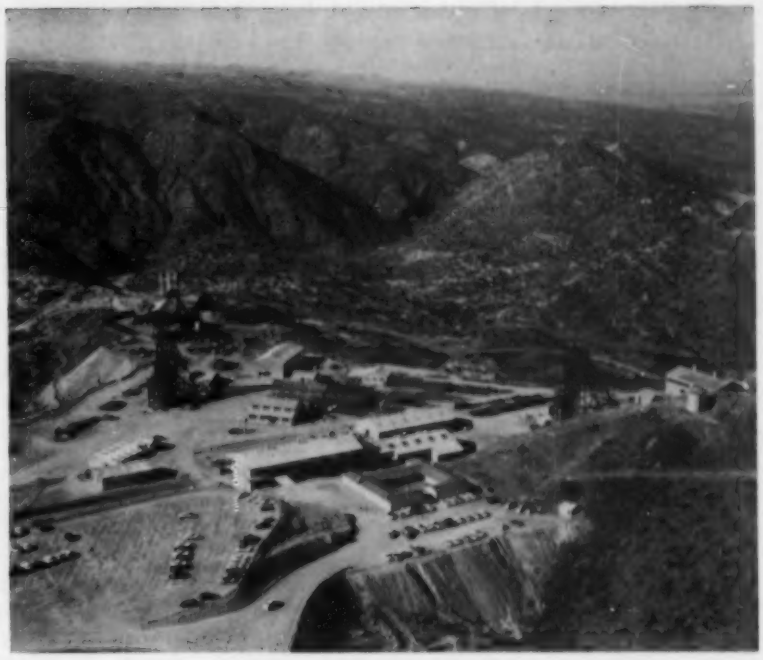
99% OF ALL CAT MOTOR GRADERS ARE STILL IN USE

New Mines



San Manuel Copper Corp., Arizona

Annual Review

Underground Mining

Edited and Compiled by Elmer A. Jones

Assistant General Manager, St. Joseph Lead Co., Bonne Terre, Mo.

New Machines

Joy extensible conveyor belt

Underground Mining — The Trends in 1955

Drilling—smaller bits, alloy steel drill rods

Blasting—pneumatic hole-charging machines

Haulage—larger units, trackless haulage

Shaft Sinking—concrete-lined circular shafts

Hoisting—multiple-rope, friction-drive hoist

Electrical Control—automatic pumping stations

Introduction

by Robert H. Ramsey

LIKE the caboose on the end of a long freight train made up of mineral and metal processing and consuming industries, the mining industry progresses according to the movement of the train to which it is coupled. Sometimes the caboose rolls smoothly; occasionally it bumps along on the ties; almost always it is under criticism from someone for being too small, too large, too expensive, foolishly progressive, or hopelessly out of date.

We who ride in the caboose are used to the rough by now, but it is nice now and then to have a bit of the smooth. Last year the train of industrial production rolled ahead swiftly and smoothly, and, except for a hot-box caused by strikes in copper mines, so did the caboose. As is brought out elsewhere in this issue, the outlook for 1956 is for more of the same.

Although the immediate prospect is excellent, mining men must look far ahead. Year by year ores mined in the U.S. are, in general, of lower grade or more complex and difficult to treat. Assuming no increase in efficiency, it becomes apparent that mining costs will increase, particularly in view of the inexorable rise in wages. Substantial price increases can neither be welcomed nor counted upon because of competition with other materials. The long-term outlook for the mining industry, therefore, appears to be for a squeeze between rising costs and lowered income per ton of ore. For certain companies this problem is more acute than for others, but in general the industry faces an increasingly critical struggle to avoid this squeeze. The following are the principal weapons the industry has in this fight:

New Orebodies: The spotlight on new discoveries is, of course, held by uranium, both in the Colorado Plateau area and in other areas such as the Pacific Northwest. Actually the fever of the uranium industry has died away and a more sober period of production has taken its place. The entrance of three or four large new companies into the mining field will be watched with interest.

Elsewhere, exploration carried on by practically every mining company is proving that there are still discoveries to be made in the U.S. Magma Copper is developing a new replacement orebody in limestone to the east of its old workings. Anaconda is carrying out an even more extensive Greater Butte Project on a low grade zone not previously regarded as ore. In this relation it appears significant that competent exploration geologists are among the men now in heaviest demand by mining companies.

Diversification: Along with the search for new orebodies, several mining companies are trying new fields: Anaconda, for example, in uranium and aluminum; New Jersey Zinc not only in titanium mining but also in production of titanium pigments; and Freeport Sulphur and Pittsburgh Consolidation Coal going into potash, where newcomers American Metal and Duval Sulphur are already established. Kennecott is active in columbium, and other companies are considering the possibility of either this field or other lesser known mineral fields such as lithium and the rare earths.

The diversification trend is also leading mining companies into nonmining activities. Several, such as St. Joseph Lead, Phelps Dodge, and Newmont, are in the oil business. Eagle-Picher for some time has been a fabricator of aluminum, and Cerro de Pasco has just purchased a small wire and cable fabricating company. This trend will probably grow as mining companies seek a wider and firmer basis for their operations.

New Equipment: As part of the effort to keep costs down, operators and manufacturers are united in developing stronger, more easily handled, and more efficient equipment. This generally results in steadily increasing capital expenditure either to outfit new operations or to replace obsolete equipment in existing mines. For example, the capital investment required to launch the new Indian Creek operation of St. Joseph Lead in southeast Missouri amounted to about $7 million. The mine and mill, providing employment for 110 men, are as fully mechanized as is possible. The cost of setting up such a mine with a plant capable of handling 2000 tpd is approximately $64,000 per man.

Research: In order to develop new equipment and provide for its optimum operation, mining firms have been devoting more funds to research facilities. Not long ago research was regarded as something carried on by technicians in antiseptic laboratories, but today the word *research* covers a tre-

mendous range of activities. A man running a laboratory flotation cell or a loader underground may be carrying on research.

It would be impossible to estimate the size of current expenditure on research in the mining industry, but it must be a substantial part of the many millions of dollars now spent on research yearly in the U.S. Anaconda Copper is one of the few companies that has for years carried on research in underground mining. This year St. Joseph Lead set up a mining research department in southeast Missouri, and every phase of the mining operation will come under scrutiny. One large mining company is attempting to apply to mining the principles of Operations Research that have proved so successful in the manufacturing industries. This company is doing fundamental research exploration in drilling, in blasting, and in loading.

A great deal more research on mining methods has been done outside the U.S., probably because the pressure of handling lower grade and impure orebodies has been greater in some European countries than here.

Many recent trends in mining techniques have resulted from research. The following developments were most evident in 1955:

Drilling: There is a trend toward smaller diameter bits, airleg drills, and alloy steel drill rods. Many show preference for tungsten carbide insert bits forged as part of the rod, although carburized steel rods at one property outlasted three to five tungsten carbide bits per rod. Rotary-percussive drilling is being investigated in parts of Europe. Rotary drilling is being tried in nonmetallic mines with encouraging results.

Blasting: The smaller diameter holes produced by the new drilling technique are harder to load. To counteract this, the Boliden mines in Sweden use a pneumatic hole-charging machine and are breaking drift rounds up to 20 ft long using burn cuts. Some mines in this country are trying both techniques. A booster charge of slow explosive is employed to clear the cut with millisecond timing used for the other holes. Results emphasize the need for special explosives and other blasting supplies to permit closer control of rates of detonation, to secure accurate timing, to avoid sympathetic detonation, and to increase loading densities in small diameter holes.

Loading and Haulage: Intensive study is directing the trend toward larger units, some of which combine loading and haulage, as in the 10-car train plus loader used at one property. Trackless haulage is certainly on the increase and probably approaching the ultimate with the nonmetallic miner in room and pillar excavation.

Shaft Sinking: The trend is toward circular shafts in which there is at least one large service compartment to handle large mechanical units. There has been a rash of new mucking devices, mostly of the clamshell type.

Hoisting: Increasing attention is given the multiple-rope, friction-drive hoist. It is strange that this hoist should suddenly arouse so much interest. The friction drive, or Koepe, hoist has been used in Europe for 20 or 30 years. At the Renstrom mine in Sweden an automatic Koepe hoist with push-button controls and other automatic equipment allows one man to draw, transport, dump, crush, and hoist 425 tons of iron ore per shift.

Electrical Control: Electricity can supply a good many of the answers to the problem of increasing productivity of manpower, which is by far the most expensive aspect of mining costs. Automatic pump stations are becoming commonplace, but much remains to be done by way of controlling haulage and hoisting in almost every mining property.

From its original use for drift back support, rock bolting has spread to raises, shaft stations, underground hoist rooms, and stopes. Here rock bolts are used in stabilizing a conveyor station at the Gaspé Copper Mines Ltd. in Quebec.

Arizona

by C. L. Pillar and H. J. Steele

Carlsbad District

by Henry H. Bruhn

Arizona

San Manuel Copper Corp. has completed sinking No. 3A and No. 3B ore shafts and No. 4 supply shaft. Haulage and grizzly level development is progressing. Stoping was scheduled to start in December. Milling of development ore is under way.

Miami Copper Co. has essentially completed mining activities in the old portion of the orebody and 75 pct of current underground production is from the newly developed low grade orebody.

Magma Copper Co. is continuing exploration and development of the limestone replacement ore zone in the east section of the mine. In the west and central divisions the 4800 level is being developed for stoping.

Pima Mining Co. ceased all underground operations at the end of September 1955, and preliminary preparations for stripping are under way to develop the orebody as an open pit.

Inspiration Consolidated Copper Co. has exercised its option on the Christmas mine, about 45 miles south of Inspiration. The old shaft is being deepened to develop ore at a lower horizon.

Iron King mine, Shattuck Denn Mining Corp. In January Iron King's new No. 7 shaft was completed to 1809 ft, and development of the 1809 level is proceeding satisfactorily. Installation of a gyratory crusher at the shaft, a conveyor belt system to convey ore to the secondary crusher, and a 600-ft conveyor to transport waste to the glory hole was completed. Hoisting of ore from the new shaft started in February.

Carlsbad District, N. M.

The year 1955 was marked by many developments and improvements in underground mining methods in the Carlsbad area. A general trend toward use of rubber-tired Universal undercutters in the place of shortwall machines has been common to this area.

At the **U.S. Potash Co.** new-type Joy continuous miners designed for potash use were put in service. These machines were connected to existing rail haulage with Joy extensible conveyor belts and 36-in. underground belt conveyors, which load cars by means of Stamler automatic equipment. Large-scale mining of pillars left behind on first mining was carried on during the entire year. Methods of recovering these pillars and lowering the 1000 ft or more of overburden without fracture to the surface were handled quite successfully. A new ore pocket and development of higher ore horizons was started during the year.

At the **Potash Co. of America** mine all loading machines, shuttle cars, and haulage locomotives are being replaced with continuous mining machines and belt conveyor haulage in new mining areas. Five continuous miners designed, developed, and built by PCA have proved so successful that seven more are to be built. An underground ore bin 42x110x20 ft was excavated with a Joy continuous miner. This 3000-ton bin, fed by conveyor belt, is a surge pocket between the continuous miner operation and shaft hoisting. This system will give PCA the longest underground belt conveyor installation in the country—total length will eventually be 7½ miles.

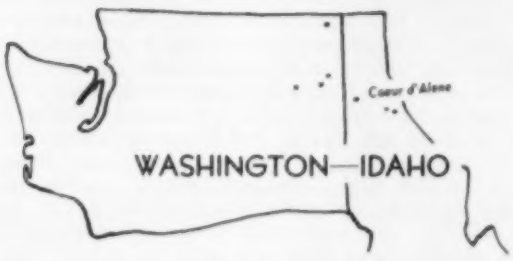
At **International Minerals & Chemical Corp.** ore skips were enlarged, the automatic hoisting cycle was speeded up, and improvements in control devices were installed. Hoisting ropes were put in service with three electrical conductors imbedded in the hemp centers for telephone circuits. Cars using modern streetcar-type magnetic rail brakes permit greater speeds on downhill hauls.

At **Duval Sulphur & Potash Co.** a new 100-hp rubber-tired diesel-powered bulldozer has proved satisfactory. A new company-built diesel-powered truck carries tools and blasting supplies to last the powderman a full shift. All diesel equipment is supplied with scrubbers. A 615 ft x 30-in. conveyor belt, having a capacity of 500 tph, was installed in one panel to feed the main line belt, which runs to the shaft.

At the **Southwest Potash Co.** a four-wheel diesel tractor is being used for general cleanup in the mining areas. Initial mining at this property was largely confined to the northern edge of the orebody with extraction of about 55 pct of the ore. Following this, a second mining consisting of pillar robbing on a modified longwall retreat basis resulted in 85 to 90 pct ore extraction.

National Potash Co., a newcomer to the area, plans limited production in 1957. The company is sinking two 15-ft diam shafts to 1750 ft. Installation of a 22-mile water line and a new refinery are under way. Santa Fe RR is extending a track to the mine site, and roads are being completed.

Farm Chemical Resources Development Corp., also a newcomer to the area, has been formed by a National Farmers Union merger with Kerr-McGee Oil Industries Inc. and the Phillips Chemical Corp. A core drillhole has been drilled at the proposed shaft site to the top of the salt. A 10-in. cable tool hole was also drilled through the Culebra limestone as a test for water, and further core testing of the salt section is in progress. The company plans to let bids for the first shaft in the near future, with production slated for 1959.



by J. D. Forrester

Coeur d'Alene District, Idaho: Although the district is still feeling the effects of a depressed lead and zinc market, several major projects were started or continued during 1955:

In Lake Gulch, southwest of Wallace, the **American Smelting and Refining Co.** and **Day Mines Inc.**, marking the culmination of several years of shaft sinking and development work, jointly placed the Vulcan or Galena mine in production of 350 tpd of copper-silver ore.

Lucky Friday Silver-Lead Mines Inc. completed its new deep shaft to the 2300 level, and development on the new level has apparently been fully up to expectations. East of Lucky Friday, **Hecla Mining Co.** and **Bunker Hill & Sullivan Mining & Concentrating Co.**, with the benefit of a DMEA loan of $529,185, began sinking a 2800-ft vertical shaft to explore what is considered to be a promising large area owned by Silver Mountain Lead Mines Inc. The operation is managed by Hecla Mining Co., and Hecla and Bunker Hill will receive 75 pct of any future production from the property and Silver Mountain, 25 pct.

On Big Creek, west of the Sunshine mine, Bunker Hill has been exploring its Crescent mine. Several important silver ore shoots have been opened on the 3000 level along the Alhambra fault-vein structure, which was productive on levels above the 1200.

At Burke, the Hercules mine of Day Mines, a famous producer in past years, has been reopened and deepened to the 1600 level, where a zinc-lead silver ore shoot has been revealed by drifting to the west. The ore produced is being treated in the Sherman mill of the Day Mines Co.

In the area of methods and equipment, the Galena mine began using sand from mill tailings for stope backfill. The Dayrock mine of Day Mines, which has used this method for several years, has experimented with steel pipe chutes and adopted this system throughout the mine this year.

Hecla has three diesel locomotives operating in the long Star tunnel at Burke, and the Crescent mine of Bunker Hill has one diesel locomotive in its Hooper tunnel on Big Creek. Three mines, the Galena, Hercules, and Sunshine, are using tungsten carbide bits exclusively. The trend is to smaller steel sections and bit sizes; 1½ and 1⅝-in. bits are generally used.

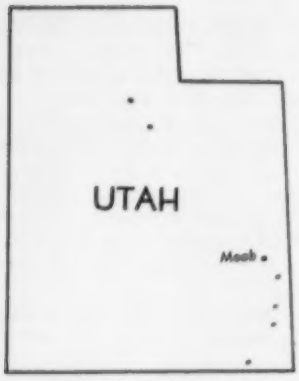
It has been announced that **The Anaconda Co.** has perfected a process to treat high-aluminum clays for the aluminum content. The company is acquiring extensive clay-bearing lands and will begin a broad drilling program in Latah County, Idaho. The successful development of such a venture will be of major importance in the overall minerals industry of the North Idaho region.

Northeastern Washington: Although there has been sustained production during 1955 from the **Pend Oreille Mines & Metals Co.** and the **American Zinc Co.** in the Metaline Falls area, uranium takes the spotlight with the discovery of productive deposits of autunite and uranophane by the **Daybreak Uranium Co.** north of Mount Spokane and by the **Dawn Uranium Co.**, a subsidiary of Newmont Mining Corp., on the Spokane Indian Reservation. This work is being done on property formerly controlled by **Midnight Mining Co.** Principal deposits lie along the southeast flank of a northeast-trending fold in Paleozoic metasediments. A self-propelled 5-in. wagon drill is used for prospecting, and 3-in. holes are drilled with tungsten carbide insert bits. Cuttings are removed from the hole by air and collected in sampling boxes built integrally into the drill carriage. Holes are drilled to 185 ft with average progress about 250 ft per drill shift. Ore has been shipped to the **Vitro Chemical Co.**, Salt Lake City.

Another uranium-bearing area near Elk, about 40 miles north of Spokane, produced ore during the year. Secondary minerals are found closely associated with pegmatitic granite, and crystal clusters of pure autunite weighing up to 80 lb have been found.

The AEC recently has reopened an office in Spokane and a staff of three geologists is assigned to work in the area.

Full train loader, called the whup d' whup, is expected to increase speed of driving drifts and tunnels. The loader was put into operation at the San Francisco Chemical Co. mine during 1955.



by Roger V. Pierce

In Utah underground metal mining emphasis during the past year has centered on numerous developments in the uranium fields along with continued production in the major lead-zinc mines. In nonmetallics, both phosphate and gilsonite have been in the forefront.

Uranium: Variations of room and pillar stoping with later pillar recovery are popular. Drifting follows the standard practice, loading being handled by the overshot mucking machines. In stopes, slushers and jackleg drills are a popular combination. In cases where larger tonnages exist, mining methods follow variations of certain coal mining practices. The Gismo, which had its inception in the bedded deposits in Washington, is also being used. In such cases ore is loaded into rubber-tired trucks and dump scooters. There are many instances where rubber-tired drill jumbos mounted with long-feed automatic drills are used.

During the year there have been numerous consolidations of existing firms, pointing toward central management set-ups to handle mining of several orebodies.

Lead and Zinc: In one district all drilling is carried out by jackleg-mounted drills, and stopers and drifters have been replaced. As a consequence, drilling efficiency has increased almost 100 pct. Integral steel with a tungsten-carbide chisel insert bit is standard. As the bit is worn to almost the diameter of the shank, the bit end of the steel is beveled to fit one-use bits and used until completely worn.

In another major lead-zinc mining area in the state, emphasis is on continued studies in the use of jacklegs, further adoption of roof bolting, and the use of tungsten-carbide bits with alloy drill steel.

Increasingly wider applications are found for roof bolting, mainly in stoping areas. This has decreased timber requirements, bringing about savings in labor, materials, and transport.

A newly designed pumping installation for underground water flow automatically controls seven underground pump stations, each with duplicate pumps. It is possible to control the entire water problem with the supervision of one roving maintenance and repair man on a one-shift basis. Warning systems at several strategic points advise when trouble develops.

One of the major mines is currently using the first of two diesel locomotives for tunnel haulage in lead-zinc mining and is increasing the depth of an underground shaft by the use of a hydromucker.

Gilsonite: In eastern Utah the major producer, **American Gilsonite Co.**, is currently sinking a four-compartment shaft 800 ft deep using two 2-yd clamshells, each operated by a line from a double-drum hoist located on surface.

Underground mining methods are being changed from dry-type mining to entirely wet operations, highlights of which are:

1) Adoption of a 200-lb pressure hydraulic feed, utilizing ¼-in. to ⅜-in. nozzles, for cutting gilsonite.

2) Use of car with rotary cutter, where hydraulic feeds are not effective, to cut a kerf or channel outlining the size of the drift. Once the channel is cut,

In the gilsonite mines of eastern Utah mining methods are being changed over to an entirely wet operation. Here an hydraulically controlled cutting jumbo is being used to cut a kerf in a drift in the Bonanza vein. Once the kerf is cut, the central area of the face disintegrates from internal pressure and is sluiced away.

the central area disintegrates from internal pressure and is sluiced away from the face.

Phosphate: Utah's largest producer currently has under way a sizable underground development program that will be used to augment production of ore that has been coming from open pit operations. With problems of meeting a low selling price, maintaining rock grade, and reclaiming ore from widths of approximately 5 ft, the reduction of costs wherever possible is necessary if the industry is to operate at a profit.

In the narrow veins, with dips varying from vertical to horizontal, flexibility and close supervision of mining are a necessity. Nevertheless, the trend in drilling is toward jacklegs in the stoping areas and long-feed jumbos in the tunnels and drifting operations. Slushers are widely used and their further adoption is anticipated. Haulage is carried out by battery locomotives on the underground levels, with diesels in use on the tunnel hauls.

A new development, the full train loader, is expected to increase speed of driving drifts and tunnels, lower car servicing time in mine headings, and reduce the number of switching stations and laybys. Such a loader, locally called the *whup d' whup*, was put into operation at the **San Francisco Chemical Co.** mine during 1955.

This loader is actually a slusher hoist operating a scraper that pulls the rock from where it has been loaded in the front end of the train back along the length of the train. Thus, the train of bottom-dump cars forms a traveling self-contained transfer system which is designed to move a full 8-ft drift round of more than 50 tons. It is placed in operation without being necessary to make any set-up of auxiliary equipment.

Nonmetallic Operations

by Al Rickard

Limestone: One of the problems encountered in the mining of limestone by underground methods is the ever-present need to place men in a position where they can inspect the roof and walls of the mine and remove loose rock which would otherwise be a hazard to men and equipment. In extremely high stopes this necessitates the development of special equipment for elevating men into working position.

Mississippi Lime Co., in its underground operations at Ste. Genevieve, Mo., has solved this problem through the use of a mobile man lift consisting of a working platform mounted at the end of a two-piece articulated boom. The booms are hydraulically operated and are controlled from the working platform. They may be rotated on their turntable mounting through 270° and may be raised either separately or simultaneously to the full 100-ft lift of the machine. The effect is to allow the men working from the platform a free choice of platform positions for the work to be done within the range of the booms. The machine, which was built for Mississippi Lime Co. by **Mobile Aerial Towers** of Fort Wayne, Ind., has proved to be safe and efficient and is well suited for scaling high roofs and walls in room and pillar mines.

During the past year, numerous advances in methods, equipment, and production have been made at the **Missouri Portland Cement Co.'s Sugar Creek mine,** located at Independence, Mo. A self-propelled jumbo mounting two percussion-type drills on a self-propelled carriage was recently placed in operation. This machine was designed for drilling flat or inclined holes anywhere from floor level to 19 ft above the floor. In the short time this unit has been in service its use has increased the drilling rate in the interbedded limestone and shale by 275 pct.

Considerable work has been done on methods of predetermining cracks and failures by means of steel and extruded rubber roof compression pads. The primary purpose of this pad is to check roof bolt tension, but it has been found that these pads give a very sensitive indication of weight, taking in any area, and at present they are being used as indicators of roof condition in the active mining area. With some modification this pad could be used to interpret roof conditions from the time an unsupported area is opened until roof failure.

Intermittent tests have been conducted throughout the past year on small hole 1½-in. rotary drilling in limestone. The tests have proved conclusively that this type of drilling is practical and will result in lower drilling costs in certain types of ground. In comparison to percussion methods, drilling speed is in the order of 300 pct greater. Also, rotary drilling results in a smooth-sided hole that greatly facilitates powder loading. The drill itself is hydraulic and very little more complicated than a wagon drill. Bits are two-wing tungsten carbide, with a hole and pin-type connection. Such a drill is expected to be placed in production in the very near future.

Now in the process of testing is a Canadian detachable tungsten carbide rock bit that has an extra long, tapered, nonthreaded skirt. The connection is made on tapered, untempered drill steel, using shim stock between the steel and the bit. Preliminary tests show good drill speed and bit life.

In the expansion program at the **Jonathan mine** of the **Columbia Cement Div.** of **Pittsburgh Plate Glass** at Zanesville, Ohio, a number of unique features have been employed. Faced with the need of increasing production from 25,000 to about 80,000 tons per month, the company plans to use the best of available equipment and build the rest to fit the operation. One of such units is a four-drill jumbo operated by two drillers from seats with all remote controls on the drills and on the hydraulic system that positions the drills. Compressors will be underground near the working sections.

Development is under way for an underground crusher station consisting of a feeder, primary crusher, secondary crusher, oversizing screens, and the necessary belts to carry the −⅜ in. product directly to the cement plant about 1800 ft from the crusher. When this phase of development is completed, haulage will be changed over from 7½-ton rear dump diesels to 22-ton rear dump diesel trucks that will take the stone from diesel overhead loaders to the crusher.

In conjunction with the **U.S. Bureau of Mines Applied Physics Branch,** a three-year project to develop a mine design is nearing completion. This project included physical properties testing of core samples, roof bolting tests, and the widening of a 100-ft long experimental room with stratascope records of roof separations, accurate roof sag measurements, and microseismic records of roof noises.

Uranium Activity on the Colorado Plateau

by Edward L. Clark

The many modes of uranium occurrence, the varied prevalence of the leasing system, and a great influx of operators from all parts of the country have brought about the apparently haphazard mining methods of the Colorado Plateau. But now the industry is undergoing an evolution that will result in greater profits. Extraction of thin and low grade deposits is being made possible as individual companies adapt their methods to the character of the orebodies.

High mining costs prevail in remote areas, with the result that many operators have been able to mine only high grade ore. Values lost by incomplete exploration and poor methods of extraction have focused attention on the possibility of strip mining. Stripping such as is now under way at the Rattlesnake mine of **Continental Uranium Corp.** is being carefully watched to determine its adaptability to other deposits. Many smaller open cut operations have proved particularly profitable due to lower mining costs and complete ore extraction. Equipment employed varies from a bulldozer or front-end loader to the heavy power shovels, scrapers, carryalls, and trucks. Contract stripping has been favored to reduce capital investments.

When deeper orebodies were developed, gophering gave way to open stoping and variations such as stoping without support or open stopes with pillar and timber supports. Nevertheless, gophering is still necessary to extract small lenticular fingers extending from the main orebody.

Loading and hauling equipment varies with the size of stope and the bottom contour of the orebody. Tractor-loaders require a minimum height of 8 ft and sufficient width to maneuver. In smaller stopes conventional mechanical loaders and slusher loaders are rapidly replacing hand shovels. Shuttle buggies, dumptors, trucks, and cars on tracks are hauling most of the ore, but the shapes of many orebodies have continued to dictate the use of the wheelbarrow with or without the aid of a puller.

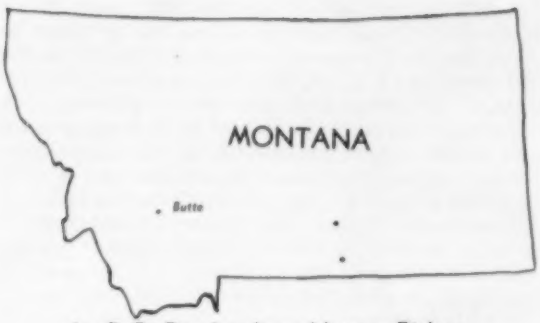
The use of inclines as entry into an orebody has been so popular that many operators have lost their perspective. Many of these inclines have been driven more than 500 ft on a 20° to 30° slope to reach a position that could have been obtained with a shaft less than 125 ft deep. Use of the large churn drillhole and the calyx hole as a shaft is increasing.

Hoisting is from incline or vertical shaft with bucket, skip, or car. Skip pockets are in use at the larger mines. Most of the smaller operations employ a side or end-dump car without mechanical dumping devices or a bucket that can be tripped with the use of an inclined apron. Bucket hoisting on wood or rail guides up an incline is common.

In summary, mining procedures in the Colorado Plateau include nearly any conceivable combination of methods and equipment except block caving and shrinkage stoping. Planned operations are taking the place of *just digging*. The impact of the change now going on is reaching down to the independent lessee who is abandoning his pick, shovel, and wheelbarrow for the slusher, shuttle buggy, and bucket or car. These changes will be reflected in extraction of greater tonnages, less loss of ore in place, and a greater efficiency.

Note: See U. S. Bureau of Mines I.C. 7726 for additional information on uranium mining on the Colorado Plateau.

LEFT: Portal of incline which is typical of the many small operating mines throughout the Colorado Plateau area. A mine need not be big to produce uranium economically. Shuttle buggies, dumptors, trucks, and cars on tracks are all moving rock and ore in these properties. ABOVE: This operator prefers tractor-loader for haulage—some even use wheelbarrows.



by E. R. Borcherdt and Lester Bishop

At **The Anaconda Co.'s** mines in Butte about 15,000 rock bolts per month are used, since they have largely replaced timber in sills and stopes. Slushing in stopes has increased, for the substitution of square-sets by rock bolts has permitted the use of higher powered slusher hoists with larger buckets.

Drill rounds have been growing in depth, necessitating an increase in the use of tungsten carbide bits. This has resulted in a change-over from 8-in. 45 pct powder sticks to 16-in. 30 pct sticks. As only the last stick is tamped, the effect is the same as with space blasting. Stopers are being replaced with push-feeds. The use of classifier sand tailing for filling stopes is being extended to more mines.

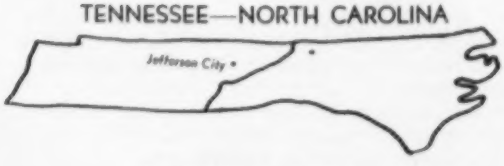
It is believed that in the untimbered cut and fill stopes much hand work entailed in scraper clean-up operations will be eliminated by an Eimco 630 tractor loader. The loader is equipped with a 32-cu ft hopper with bottom discharging gate.

At the **Kelley mine** concrete is replacing timber in the grizzly and slusher drifts, with collapsible steel forms used in place of wood forms. The caving method, in general, has been changed from the gravity method below the grizzly drifts to the slusher method, with loading by scrapers.

Considerable surface churn drilling has been done, both for prospecting low grade areas and for passing concrete to underground workings. Copper-bearing areas close to the surface, but not connected to the block caving reserves, are being exploited by open pits.

Using the Cryderman mucker, the new **Jib mine** shaft in the Basin area has been sunk to the 300 level by Roger Pierce and his associates.

Favorable reports about the use of high pressure feed rotary drills in the headings in phosphate rock have been received from **Victor Chemical Co.** at **Maiden Rock.**



by William E. Black

American Zinc Co. of Tennessee: The **Young mine** is still in the early stages of development and production. This mine is laid out to incorporate the Gismo system of mining, which was developed at this company's Grandview mine in Washington. Haulage drifts are being driven in the footwall, from which raises will be developed into the ore, and in that part of the ore horizon which has been cut by drifting, stopes are being opened up. Total production is at present on a relatively small basis, but an output of 1000 to 1250 tpd is expected by the end of the first quarter of 1956.

At the **Coy mine,** shaft sinking and the breaking off of levels has been done. This mine will also be developed for the Gismo system of mining. Production is expected during the latter part of 1956.

West New Market Area: Exploration of this area, comprising over 7000 acres of land in Jefferson County, Tenn., is under a DMEA contract. With nine diamond drills operating in the area for more than a year, approximately 250,000 ft of holes had been drilled by the end of September 1955. Results of the project have been encouraging. About 36 pct of the holes drilled have found commercial ore. To date the drilling has indicated some very large orebodies and an unusually large tonnage of mineable ore.

When use of carbon drill steel resulted in excessive breakage, intra-set tungsten carbide inserts in alloy drill steel were adopted for drilling hard rock with percussion air tools. Average footage per drill rod, for more than two years, has been in excess of 900 ft. In an effort to reduce steel cost, the present practice is to purchase drill steel and inserts separately and braze in the inserts in company shops.

The New Jersey Zinc Co.: The **Jefferson City mine** is expected to reach a production stage during 1956. The hoisting shaft, which is to be sunk to 1302 ft, has reached 1250 ft. The ventilation shaft is complete at 1217 ft, and development of mining levels is now in progress. Surface shops and administration building are nearing completion, and the construction of a 1000-ton flotation mill has commenced.

At the **Flat Gap mine,** located at Treadway in Hancock County, Tenn., necessary preparatory work is nearing completion, and a hoisting shaft will be sunk. The ventilation shaft, which will connect with the first mining level, will be 275 ft deep.

Zinc Mines Works of U.S. Steel Corp.'s Tennessee Coal & Iron Div.: The use of diesel-powered mine locomotives in this operation has merited much favorable comment. In 1949 four such locomotives were built, and a fifth was recently added. Each locomotive is of the trammer type, 48 in. high, 39 in. wide, and 14 ft long, and pulls an average of 16 loaded Lorain cars per trip to the mine shaft at an average rate of 4.7 mph. The engine is equipped with exhaust gas conditioners attached to the front of the unit. The cars are 35-cu ft capacity, weigh 2000 lb each, and carry 1¾ tons of ore. Phones mounted on the locomotives provide communication with various parts of the mine and with the surface. Small diesel-powered bulldozers equipped with angle dozer blades and exhaust gas conditioners are also being used successfully underground. These machines are used to recover broken ore in the old

areas of the mine and also handle current production in conjunction with slushers and air shovels. Airleg drills have replaced column-mounted drills in stoping, but drill jibs are still used in development headings.

Appalachian Sulphides Inc.: This company is a wholly owned subsidiary of the **Nipissing Mines Co. Ltd.** with head office at Toronto. Appalachian owns and operates the Elizabeth Copper mine at South Strafford, Vt., and the **Ore Knob** copper property near Jefferson, N.C. The latter mine produced some 300,000 tons of ore during the 1870's and 1880's. Core drilling was carried out on the property in 1954, and the tonnage at present indicated below the old workings is 1,219,700 tons, averaging 3.09 pct copper. A vertical shaft, now about half completed, is being sunk to a depth of 1220 ft. Preparations for the erection of permanent surface plants are also under way. Appalachian Sulphides Inc. is also carrying on mineral exploration elsewhere in North Carolina and Virginia, and a core drilling program is under way in the Virgilina copper area.

Drilling Practice

by J. Fred Johnson

In contrast to large tonnage open pit operations, where the objective of attaining a minimum cost per cubic unit of blasthole excavation dictates the largest diameter holes and massive equipment, the limitations of underground mining dictates lower linear unit costs by drilling holes of minimum diameter.

Realization of the value of small diameter holes received its initial boost in the U.S. some seven years ago, and since then diameters of drillholes, sizes of drilling machines and drill steel, and weight of drill set-ups have been reduced 50 pct, with a corresponding reduction in original cost of the total equipment and overall reductions in mining costs.

Advances in 1955 have been along the lines of further perfecting light equipment and broadening the scope of its use underground:

Drill Bits: The old multiple-use threaded steel bit has been increasingly supplanted by throwaway or one-use steel bits of the smaller diameters permitted by elimination of stock threads and by tungsten carbide bits of both integral and detachable designs. Improvements in the alloy steel used for bit stocks has allowed thinning of stock walls and have so lengthened the life of stocks that smaller diameter tungsten carbide inserts have been made possible. Life of the stock now approximates the life of the insert.

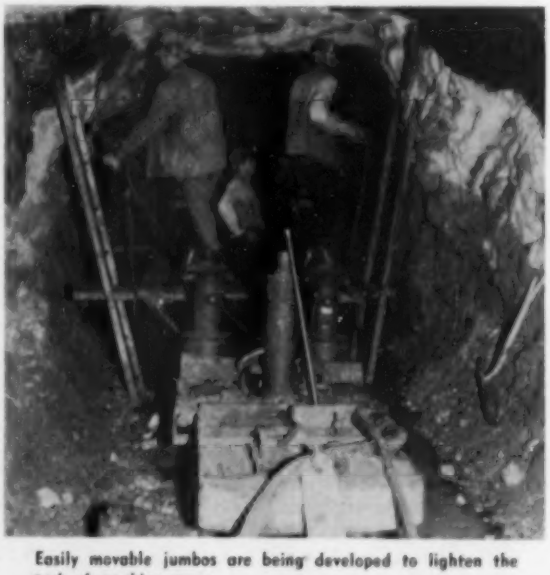
Drill Steel: Changes are being tried and perfected in design and fabrication of drill steel to eliminate the notches due to heat treatments. The most promising change currently being tested is fabrication of the steel, followed by carburizing of the complete unit to effect a hardened surface shell and water hole, with a ductile zone between. This carburizing apparently closes the incipient cracks on the outside of the steel and in the water hole, from which steel breakages spring. Carburized drill steel life sufficient to wear out three to five tungsten carbide inserts has resulted.

Longhole Drilling: The lower brackets of longhole drilling have been invaded up to some 20 to 30 ft by flat flexible drill rods. With these rods such hole lengths can be drilled transverse to an opening 6 ft square without great impairment of drilling speeds. Above this length the use of fully carburized rods and sleeves carburized on the inside only has so reduced breakage that one test attained 28,000 ft of longhole drilling before any failure. This considerably broadens the scope of longhole drilling, both for exploratory and mining purposes.

Machines and Mountings: For bit diameters up to 1⅝ in. jackhammer-type machines are used. For larger bit diameters and for longhole drilling, heavier machines have been perfected by American manufacturers. Jackhammer drilling from airlegs has become accepted practice, but solid jumbos or easily movable jumbos with chain-fed machines are used when a number of holes are to be drilled from one set-up or in a stope cycle where one man operates more than one machine. Machines are being developed that make the work of the machine man lighter, and there is a move towards faster and lighter blows, which prove easier on equipment and contribute to speed of drilling, particularly in very hard rocks.

Innovations: Further progress is being made in the use of smaller diameter bits. Such a combination has been found very effective in drilling extremely hard rock, but the difficulties of obtaining dynamite cartridges of small enough diameter have made its general adoption a slow matter. The problem of getting enough explosive in such small holes to effect desired breakage has been overcome in some cases by pneumatic loading of longer dynamite cartridges.

Tests initiated by the U.S. Bureau of Mines at Rifle, Colo., in rotary drilling 16-ft holes of 2-in. diam proved technically successful for soft rock only, but further testing of this technique, with the addition of percussion in the cycle, seems destined to extend percussion-rotary drilling to hard rock. Such technique has reportedly already made possible the speed-up of oil-well drilling in hard rock formations.



Easily movable jumbos are being developed to lighten the task of machine men.

Shaft Sinking Trends

by C. Kremer Bain

Although the design of shafts is almost as varied as the number of individuals engineering them, there is one basic principle involved, namely, meeting the production needs and providing efficient service of supplies for the particular operation involved.

Increased use of mechanical equipment underground has necessitated a change in shaft design from the small compartments in line to dimensions that will accommodate larger skips for production and at least one large service compartment for handling larger mechanical units.

There is a trend toward substituting steel and concrete shaft sets for timber, and the use of concrete rings and monolithic concrete linings is becoming more general. Circular concrete-lined ventilation shafts are now more commonplace. The advantages of reduced air friction, elimination of fire hazards, long life and low maintenance costs are apparent, but there are also the following important advantages: there is a high percentage of usable area to total excavation; the section is the strongest obtainable, with walls practically self-supporting; unreinforced concrete lining may be used, since the concrete is in compression; simple concrete forms may be used with concrete placed uniformly around the shaft perimeter; and ground water may be grouted off behind the concrete lining.

The increased cost of labor and materials has been reflected in a trend toward further mechanization and efficient material handling. The first consideration was the elimination of the most arduous and time-consuming phase of the sinking cycle, namely mucking. There are a number of mechanical mucking devices used today in shaft sinking as compared to the hand operation of years past. The clamshell loading unit appears to be leading other methods. The manifold with hand-held rock drills is still being used quite extensively but various types of jumbos are gradually being introduced.

Headframe used in sinking one of the two shafts at National Potash Co., Carlsbad, N. M.

LEFT: Calyx drill operating near Temple Mountain, Utah, made 10 ft per day advance, working two shifts. ABOVE: Calyx drill intersected uranium ore at 200 ft when this 36-in. core was removed.

by M. G. Jones and Severn P. Brown

Iron: Important underground iron mines are operated by **Republic Steel Corp.** at Lyon Mountain on the northern perimeter of the Adirondacks and around Port Henry on the eastern perimeter. The ore is magnetite, generally of concentrating grade. The deepest level is 3200 ft below the surface, or 2150 ft below sea level. Most of the stoping is being done by longhole drilling with sectional steel and detachable carbide bits. At the Port Henry district a recent development has been the change from reaming out the undercut funnel with stopers, or mounted jackhammers, to driving a so-called undercutting sublevel connecting the tops of all 50-ft finger raises out of boxholes in scram drifts. This provides a safe vantage point for drilling longholes downward in a pattern that will funnel out the undercut, giving faster reaming with increased safety.

Zinc: The mines of the **St. Joseph Lead Co.** at Balmat and Edwards lie in the foothills between the Adirondack Mountains and the St. Lawrence Valley. In the moderately dipping, highly irregular orebodies, mining is from sublevels by a variety of stoping methods. The greatest tonnage comes from longhole drilling with sectional steel and detachable carbide bits and from underhanding with jackhammers in large open stopes. During 1955 the shaft deepening at the **Edwards mine** was finished, carrying it 400 ft deeper to the 3100 level, a depth of 2375 ft below sea level. In **Balmat No. 3 mine,** a drift is being driven through soft, water-bearing ground by placing concrete with circular steel forms one round behind the advance.

Talc: The four producing companies are setting tonnage records for the district, which is the largest in the country. The ore is chiefly a talcy tremolite which lies in folded beds of marked lateral extent. At the **Gouverneur Talc Co.** a new level is being opened and an underground 24x36-ft jaw crusher has been installed with complete ore pass system. The mine is currently turning out 350 tpd and anticipated output is 500 tons, making this one of the smallest tonnage properties to have installed an underground crusher.

New developments at the **International Talc Co.** include sinking of a new shaft to replace the present shaft at the **Anthony mine.** A rigid-frame steel construction was used for the headframe and may be the first, or one of the few, such headframes in the industry.

Gypsum: After three years of experimenting, the **U.S. Gypsum Co.** at Oakfield, N.Y., has recently converted from standard wooden props to roof bolting. A 6 to 18-in. layer of loose, hard shale immediately overlying this thin (4-ft) gypsum vein presents an extremely hazardous roof condition and has always made roof support the most important problem in this room and pillar mine. Standard 3-ft by ¾-in. roof bolts installed up to the face before each blast on a staggered 5-ft pattern have proved to be a completely safe method of roof support, with the additional advantage of facilitating movement of the loaders and shuttle cars. Bolts using an expansion shell for anchorage are employed, with a 6-in. square plate to provide bearing surface against the roof.

Missouri-Kansas-Oklahoma

by O. A. Rockwell and John W. Chandler

About 55 mining properties are at present being operated in the Tri-State District. Almost all this production is being concentrated in four large mills. The balance goes to three small concentrating plants. Through September 1955, 2,825,208 tons were treated with a metallic recovery of 1.90 pct Zn and 0.55 pct Pb. Most of the production comes from mines operated by **Eagle-Picher Co., American Zinc Co.,** and **National Lead Co.** all of which employ trackless mining methods, using diesel-powered equipment. In general, the trend is toward complete dieselized mechanization.

Most of the drilling is being done with crawler-type jumbos with various types of boom mountings. To a lesser extent, jackleg machines are employed, particularly in places inaccessible to jumbos. Detachable steel bits have been almost entirely replaced by carbide insert bits. Eagle-Picher Co. has been developing crawler-type high mast jumbos to reach ever-increasing roof heights. One has recently been put in service that can operate up to 75 ft above the floor.

About 85 pct of the loading is now being done with front-end loaders or boom-type shovels. The remainder is being loaded with electric and air slushers on ramps.

Because of the long haul, most haulage is now being done with diesel dump and semitrailer trucks to increase pay loads.

Almost all the ore is hoisted with conventional *can-type* hoists, using *cans* of ¾-ton capacity. Only two skip hoisting shafts are in operation.

During the past year longhole drilling with sectional steel to depths of 120 ft has largely replaced churn drill prospecting in close proximity to present mine working. This has proved to be very effective in finding new ore and has materially reduced development costs.

Southeast Missouri Lead Belt

by L. L. Turley

The new **Indian Creek Mine** of **St. Joseph Lead Co.**, northwest of Potosi, has almost reached full production of 2000 tpd. All mine haulage is done with electric and diesel-electric 12-ton shuttle cars and 6-ton diesel dump trucks. Loading is being done with scraper ramps mounted on an electrically propelled rubber-tired chassis. These loaders can operate in a minimum height of 9 ft.

No. 25 Shaft is the new concrete-lined circular shaft in the Lead Belt. It was sunk to a depth of 655 ft by December 1954 and was equipped during 1955. Development drifting started in November. This shaft will be connected to the **Pim mine** of the Federal group of St. Joseph Lead Co. mines by an 11,000-ft drift, 3800 ft of which have already been driven from Pim mine. The drift loading will be done with 630 Eimco trackless loaders, and the hauling will be done with 6-ton diesel dump trucks. This shaft will be used for waste rock disposal and the handling of an operating crew.

by Richard F. Moe

The major change in **North Range Mining Co.** operations has been a successful campaign to introduce longhole drilling in most of the properties. Special 3½-in. longhole drill machines with 4-ft steel changes are employed in hard material and 3-in. machines with both 4 and 3-ft changes where the material is softer. In all cases it has been found that the Gardner-Denver special alloy longhole drill steel and couplings are the most satisfactory.

The longhole drilling has been responsible for a great increase in the efficiency of sublevel stopes at two properties and has permitted the development of an adaptation of block caving at two of the others. At the latter two properties, vertical radial drill patterns are being combined with transfer drifts and drawpoints similar to those used in block caving. The material involved does not cave readily, so this adaptation of shrink stoping has been developed to handle heights of ore up to 60 or 70 ft. This system, although still in the experimental stage, has already greatly increased recovery as compared with conventional sublevel caving.

There are several other general trends being followed, such as installation of automatic centrifugal pumps, which have resulted in greater savings in labor. The use of conveyors is being continued and new ones installed.

The Montreal mine, located at Montreal, Wis., is the westernmost operating property on the Gogebic Iron Range. From the start of operations in 1886, through 1954, the mine has shipped a total of about

Crawler-boom mounted jumbo developed by Eagle-Picher Co. is being used in a Tri-State district property. Note extensive rock bolting.

40 million tons. With the exception of the depression years, annual production has averaged over 1 million tons for the last 30 years. The ore is soft, granular hematite mined by the sublevel caving system, with a 50-ft vertical interval between sublevels.

The main production shaft, through which all ore is hoisted to the surface, is bottomed at the 35th level, 2876 ft below surface. Ore from greater depths is hoisted to and transferred on this level. An auxiliary hoisting shaft has been bottomed 1459 ft below the 35th level, giving a total vertical depth of 4335 ft below surface.

Inland Steel Co.: Operations continued at the Morris and Greenwood mines on the Marquette Range, the Sherwood and Bristol on the Menominee Range, and the Armour No. 1 mine on the Cuyuna Range—all underground operations. New levels are being developed at the Sherwood, Bristol, and Morris mines. There have been some improvements in car dumping arrangements, and all pumping facilities are automatic. The Sherwood, which suffered a six-week shutdown due to a water breakthrough from an adjoining property, has been equipped with emergency pumps and a new water column. At the Morris work continued on the replacement of timber sets with steel, and advances were made in the mechanical cleaning of tracks and ditches. The Greenwood drilling is tending toward smaller bits and tapered sockets instead of threads. Work has been started on the Armour No. 2 property, for which a new shaft is planned in 1956.

The Cleveland-Cliffs Iron Co.: The Koepe ore hoist at **Cliffs-Shaft mine** "C" shaft took over the production hoisting for the mine early in December. Two underground mines with long production records were closed during 1955 when their reserves were exhausted. These were the Spies on the Menominee Range and the Lloyd on the Marquette Range.

Ontario and Quebec

by John A. Hall

Some interesting trends in the Canadian mining areas of Ontario and Quebec during the year were:

1) Diversified use of the blasthole mining method for excavating a large underground crusher station at the *Levack mine* of the International Nickel Co., ore pillars against coarse rock fill at *Waite Amulet mines*, and a million ton blast at *Algoma Iron Ore Properties*.

2) Increased employment of tungsten carbide bits and concentration on improving drill rod life through such means as *spiral rolling*.

3) Installation of friction-type hoists where advantageous conditions prevailed.

4) A definite trend in shaft sinking towards mechanical mucking. One engineer has pointed out the wide variation in compartment sizes and suggested the desirability of standardization.

5) Smooth circular steel sections of 3/16 or 1/4-in. plate that bolt together on the outside, fabricated for mill hole lining and manway cribbing. Fill can be placed around the outside of the sections.

6) Use of lightweight aluminum air line piping and fittings in some mines faced with a corrosion problem.

7) Widespread application of processing mill tailings for placing hydraulically as fill.

8) Continued improvement in underground concreting by utilizing steel and aluminum forms.

9) Rapid development of millisecond blasting technique.

10) Considerable increase of rock bolting backs and walls throughout the majority of the Canadian mining areas.

Blind River Area, Ontario: A number of uranium mines were prominent this year. **Pronto Uranium Mines** came into production in August. **Algom Uranium Mines** has two projects, **Quirke Lake** and **Nordic Lake.** These two mines are well along in development, and each mine is planned for 3000 tpd. **Consolidated Denison** is developing a large uranium orebody and has set an initial daily production objective of 5700 tons by 1957.

Halliburton-Bancroft Area, Ontario: Bicroft Uranium Mines, has development under way and expects to produce 1000 tpd by September 1956.

Sudbury District: Developments in mining practice by the **International Nickel Co. of Canada Ltd.** consisted mainly of refinements in technique and extension of improvements already under way, including:

Rock Bolting: From the original use for drift back support, rock bolting has spread to raises, shaft stations, underground hoist rooms, stopes, and box-hole brows. Bolting in stopes has permitted use of the cut-and-fill method instead of squaresets in some places. Improved techniques allow use of the regular stoper machine for bolt tightening.

Longhole Drilling: Lower drilling costs have been attained by using larger percussion drills and heavier diamond drills.

Regular Rock Drilling: The old Leyner machines are being replaced by the lighter airleg drills, and lighter steel and carbide insert bits are being rapidly installed.

Underground Haulage: In the larger tonnage mines heavy haulage equipment such as 20-ton trolley locomotives, 260-cu ft tipple cars, 188-cu ft Granby cars, and 85-lb steel rails is being installed.

Hoisting: Hoisting is being changed to semi-automatic installations with controls underground. Units are larger for handling 15-ton pay loads at 3000 fpm to depths of 4300 ft.

Stope Chutes: Use of good concrete chute lining has practically eliminated chute repairs. Wider chutes for filling long cars have speeded up the loading.

Falconbridge Nickel Mines Ltd. reports the following: **Falconbridge mine** on the South Range has completed deepening the main shaft and is preparing to sink a winze from the 3850 level to a depth of 6300 ft. The winze will have six compartments with concrete rings and steel members. A 9-ft diam friction-type hoist will serve the skip, while a 10-ft diam conventional hoist will handle men and materials.

At **Onaping mine** on the North Range a five-compartment shaft is being sunk 3300 ft, using a Cryderman mucker.

At **Fecunis Lake mine** two shafts are being sunk, one to 3311 ft and the other to 4000 ft, using Riddell muckers. The deeper main shaft, collared on top of a hill, will be serviced by an adit. Friction-type hoists will be used in this shaft. Ore and waste bins have been cut in the rock. The construction of a 2000-ton mill has started.

At **Longvack mine** a small, near-surface orebody has been prepared for mining by an inclined shaft. After crushing the ore will be brought to surface on an 800-ft conveyor.

Western Ontario: The main copper and zinc mining development was at the **Geco Mines,** located near Manitouwadge Lake, north of Lake Superior. Preparation is being made for early 1957 production at the rate of 3000 tpd. The main shaft, 32 x 8 ft, had reached a depth of 800 ft by September, the im-

mediate objective being 1500 ft. Plans call for an underground crusher at the 1400 level. Mining by blasthole drilling from perimeter sublevels is contemplated.

New underground operations are getting under way at the nickel prospect of **Falconbridge Nickel Mines,** located at Populous Lake, where a shaft is being sunk. **Maybrun Mines** also has started shaft sinking on a copper prospect south of the Falconbridge shaft.

Shaft sinking is in progress at **Wilroy Mines,** located immediately west of Geco. The objective is to explore copper and zinc ore indicated from a recently completed diamond drill program.

Chibougamau Area: Milling operations at 1750 tpd began on June 1 at the **Campbell Chibougamau** gold-copper property. Production is maintained on six operating levels from open and cut-and-fill stopes. Broken ore is handled through scram drifts or by limited tramming to an ore pass system, serviced by an underground crusher.

The first copper and gold producer in the Chibougamau area, **Opemiska Copper Mines,** utilized diesel power for their operation. An initial production rate of 400 tpd was maintained by shrinkage stoping from three levels. Subsequent development included deepening the shaft and opening up three additional levels. The ore pass system has been completed, and skip hoisting began on July 1. A mill rate of 600 tpd was scheduled for mid-November, with a mill rate of 800 tpd planned for April 1956.

Still another copper and gold operator, **Chibougamau Explorers,** is readying its plant for late November production. The initial rate will be 500 tpd, with plans for expansion to 750 tons. Mining will be by shrinkage stope methods with short tram lengths throughout. The ore pass system has been established with underground crushing.

Gaspé Peninsula, Quebec: The concentrator and smelter of **Gaspé Copper Mines Ltd.** were completed in March 1955. Production of 6500 tpd was planned for this operation, but owing to a shortage of electric power, production has been limited to 2500 tpd. A portion of the concentrate is being shipped to the Noranda smelter, as there is insufficient power for local smelter operation. (See page 184)

The mining method employed in the main ore zone consists of overcutting to a room and pillar pattern, using quarry-type benching to established floor levels. Trackless mining equipment, consisting of coal-mining-type conveyor loaders, diesel-type overhead loaders, bulldozer-traxcavators, and an electric powered 2½-cu yd shovel is in use. Haulage units comprise electric cable shuttle cars, diesel-type dumptors, and diesel dump trucks. Tractor-mounted drill jumbos, drill rigs of various types, and conventional airlegs are used for drilling. Tungsten carbide drill steel is used for all drilling operations.

Falconbridge Nickel Mines Ltd. is preparing the Longvack mine in the Sudbury District to mine a near-surface orebody.

Primary jaw crusher and secondary cone crusher stations have been established underground, with classifiers and a thickener to handle wet ore and slimes.

Hoisting is accomplished by means of a 42-in. continuous conveyor belt 2400 ft long, erected at a 19° angle. The vertical lift is 688 ft.

Noranda Area, Quebec: Located 5 miles north of Noranda, Quebec, **West MacDonald Mines** started pyrite-zinc production in August 1955. The blasthole stoping method is used and the scheduled production rate for the present is 1000 tpd.

Located 35 miles north of Noranda, **Lyndhurst Mining Co.** (copper) has shaft sinking and lateral development under way.

Porcupine District, Ontario: McIntyre Porcupine Mines has started a second main shaft that will be sunk from the 3875 ft level to the present bottom of the mine, the 7000 ft level. This shaft, estimated to cost $1.5 million, will speed up the development of the lower levels.

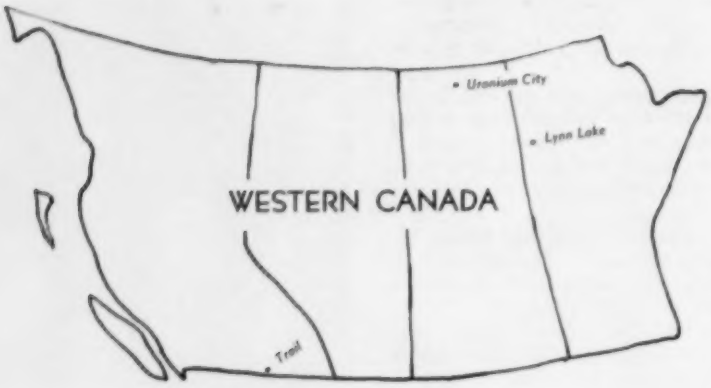
New Brunswick

by Lawrason Riggs, III

Metal mining in New Brunswick, Canada, is in its infancy, but after a major staking rush two large mines and several smaller ones have emerged.

The first producer was **Keymet mines,** a lead-zinc mine in the northern part of the province, with a 250-ton mill. In completing 700 ft of shaft sinking by the end of the summer, 1955, the new **Larder U mine,** a base metal prospect located near Bathurst, used a Joy *Orange Peel* mucking device. **Burnt Hill Tungsten mines** hold a tungsten-producing property in York County, New Brunswick, and production of concentrates at the 150-ton mill commenced in 1955. **Heath Steel Mines,** a subsidiary of American Metal Co., is developing a property near Newcastle, N.B., where three main lead-zinc orebodies currently are being drilled, tested, and developed.

The Brunswick Mining & Smelting Corp. is developing two large low grade lead-zinc orebodies in the Bathurst area, where a 150-ton pilot mill has been erected. One orebody is to be an open pit operation, initially. The other, a deep massive sulfide deposit of more than 28 million tons, has been developed on the 200 and 350 levels. Development work is trackless, with 8x10-ft drifts and crosscuts driven on one level by an Ingersoll-Rand Jumbo, Eimco 630 mucking machine, and Joy battery shuttle car. The upper level is competing with an Ingersoll-Rand jackleg, Eimco 630, and diesel Rock Carrier of 55-cu ft capacity. The latter was specially designed by the Mines Equipment Co. to work in conjunction with the Eimco loader. It is planned to sink a 2000-ft, five-compartment shaft during 1956 and 1957, install a primary jaw crusher on the 1850-ft level, and develop the mine for sublevel stoping, with 150-ft level spacing and stopes 75 ft wide by approximately 150 ft long.



by L. T. Postle

Sherritt-Gordon Mines Ltd.: The Lynn Lake, Manitoba, nickel operation continued production at two separate mines throughout 1955 at a combined annual rate of 24 million lb of nickel in concentrates. Mining is by the open stope method using longhole percussion drilling. Ore is handled through scrams direct to the crushers and then by conveyors to the shafts. Exploration work shows promise of additional ore reserves.

Gunnar Mines Ltd.: The **Ed-Bon** group of claims covers approximately 1300 acres located on the north shore of Lake Athabasca, Saskatchewan. The first uranium ore will be mined from an open pit, but sinking of a vertical shaft is planned in preparation for underground development in 1956.

Treatment and power plants have been completed, and test runs were begun August 1955. The treatment plant is rated at 1250 tpd and the sulfuric acid plant has a nominal capacity of 100 tpd, with an allowable 30 pct overload.

The Consolidated Mining & Smelting Co. of Canada Ltd.: Although underground development and a concentrator of 100-tpd capacity were completed in 1953, the **H. B. Zinc-Lead mine,** located 37 miles east of Trail, was brought into production last May.

The property remained idle from 1927 until after World War II, when an extensive diamond drilling and exploration program resulted in the discovery of the present orebody. It is a zinc-lead replacement deposit in limestone, relatively low grade, but large enough to lend itself to low-cost mining methods, using long blasthole drilling.

Pine Point Mines Ltd.: Since 1948, the firm, controlled by the Consolidated Mining & Smelting Co. of Canada Ltd., has been carrying on exploration of lead-zinc property on the south shore of the Great Slave Lake, N. W. T., under the direction of the parent company. Roughly 200,000 ft of diamond drilling has been done to date. Widely spaced cross-sectional drilling has outlined a mineralized belt some 22 miles long and from 2 to 4 miles wide, and a limited amount of closely spaced drilling has indicated several million tons of ore, of which at least 5 million tons are suitable for open pit mining.

A vertical shaft was sunk 162 ft to the ore horizon and roughly 700 ft of lateral work was done. In general, the grade of the ore checked drillhole intersections, and the work indicated that no serious mining problem exists. It is now considered that a substantial operation can be established at Pine Point providing satisfactory transportation arrangements can be made.

The Lynn Lake, Manitoba, nickel operation of Sherritt-Gordon Mines Ltd. was in operation throughout 1955 with the production of 24 million lb of nickel in concentrates.

A Report on

Underground Mining in Sweden

by Eugene P. Pfleider

Sweden has keen competition from Quebec, Labrador, and Venezuela to retain the lead as the major exporter of iron ores. This role is made more difficult by the fact that Sweden must convert the famous **Kiirunavarra mine** from an open pit operation to a wholly underground mine on the following annual tonnage scale:

Year	Open Pit	Underground
1953	8,700,000	1,500,000
1960	0	12 to 13,000,000 ore 4 to 5,000,000 waste

Further, this must be done in the face of a labor shortage, severe climatic conditions, and a pending state ownership of the principal producers, Kiirunavarra and Malmberget.

Mechanization: Lack of labor and the high cost of providing personnel facilities, estimated to be at least $25,000 per worker,[1] has forced a degree of mechanization generally exceeding that achieved in U. S. metal mining practice. Joy loaders are working on the extremely abrasive Kiruna ore and averaging 450 tons per shift when loading into shuttle cars. The **Renstrom mine,** a small sulfide property operated by the well known **Boliden Co.,** is outstanding in its use of labor-saving practices. One man is solely responsible for the drawing, transporting, dumping, crushing, and hoisting of 425 tons per shift. He relies on remote-control electric locomotives, hydraulically operated chute gates, a fully automatic friction-drive skip hoist, and a push-button cage hoist.

[1] B. H. Nordlund: *AIME Trans.*, February 1952, vol. 193, pp. 187-192.

Drilling and Blasting: Swedish mines may possibly lead in the drilling and blasting of hard rock underground. Certainly her engineers have given it intensive study[2] and pioneered in the use of small gage tungsten carbide bits, the jackleg, flexible steel, and the pneumatic apparatus for charging of explosives into drillholes. Density of loading is reported to be doubled using the pneumatic loaders. Now Swedish mining engineers are turning their attention to jumbos, sectional steel, and rotary-percussive drills. Considerable experimentation is under way to develop the *burn cut* and the so-called *Michigan cut,* using 4 to 6-in. diam center holes for blasting drift rounds up to 20 ft long.

Stoping Methods: Although cut and fill and sublevel stoping methods are employed widely, a form of sublevel caving is used in the principal mining areas of Grangesberg, Malmberget, and Kiirunavarra. Contrary to U. S. sublevel caving practice, timber is not needed because the ore and hanging wall are very competent. There is gradual subsidence behind extraction. Sublevel intervals are from 20 to 30 ft, with 12x16-ft crosscuts on about 30-ft centers. Longhole ring drilling fanning around the crosscut is employed to break the intervening ore. Kiirunavarra is planning to produce 40 tons per manshift underground and 22 tons per manshift overall, using sublevel caving with Joy loaders and shuttle cars.

[2] Janelid: *AIME Trans.*, June 1954, vol. 199, pp. 613-619.

The **Bodas mine** of **Sandviken Steel,** as well as others, avoids sublevel development in open stoping of a nearly vertical orebody by horizontal longhole drilling. This is done from a movable carriage, which travels on rails in the slightly inclined raises.

Transportation: Underground transportation in Sweden closely parallels American practice. In order to avoid secondary blasting there is an accelerated change to larger chutes, larger cars, and heavier tracks, even in the smaller mines. Hinged bottom-dump cars of 240-cu ft capacity, unloaded by a counterbalanced dumping bridge, give excellent service in the newly developed sections of Malmberget operations. Centralized underground storage and crushing stations are standard in Sweden today. Large ore chutes, up to 10x4 ft in size, handling large boulders without hang-ups, and fully automatic skip hoisting have made underground crushing mandatory. Furthermore, the footwall rocks are generally very competent, and it is cheaper to build and maintain these facilities underground than on the surface. A prime example of centralization, of course, is the new Kiruna plant designed to crush and hoist 50,000 tons of ore and up to 20,000 tons of waste per day through eight adjoining hoisting shafts and one service shaft. Service shafts are located every 1400 meters (4600 ft) along the strike of the orebody to handle men and supplies for the various producing sections.

Hoisting: All recent hoisting installations have been of the multiple-rope friction drive type.[3] Existing drum-type hoists are being converted to push-button automatic control, developed by ASEA of Sweden. The result is an increase in production and a saving in operating personnel and maintenance.

[3] Pfleider, Malmlow, Landau, *Mining Engineering*, January 1955, vol. 7, No. 1, pp. 25-40.

Research and Engineering Education: Industry is closely linked with research and the Royal School of Mines by technical committees staffed with men representing both groups. A working arrangement is thereby provided for the college students to visit the mines and collaborate in special studies. Engineering graduates in Sweden, as in all of Europe, seldom do surveying work. They are employed in operations research, development, and production. Considerable use has been made of rock stress analysis and strain gage measurements at Boliden and Malmberget, where critical problems were solved.

Trends on the Iron Ranges, Eastern United States and Canada

by Hugh J. Leach

Rotary drills used in soft rock

Larger and heavier equipment

New ammonium nitrate powder

IN open pit mining, as in other industries, it has become necessary to improve operating efficiency in order to combat higher labor and supply costs. Moreover, orebodies are becoming leaner, pits are getting deeper, stripping ratios are increasing, and hauls are getting longer. There has been a steady increase in size, speed of operation, and reliability of the various machines involved in breaking, loading, and hauling ore. Changes have seldom been radical but are rather the result of steady improvement.

Drilling: Notable advances have been made in the use of rotary drills and air powered percussion drills for blasthole drilling. Several hundred of these machines are now in use as replacements for churn drills in softer rocks such as limestone and shale. Their application to hard rocks such as iron ore and taconite is under current investigation, but in the Lake Superior iron mining district, open pit blasthole drilling in ore has been accomplished almost exclusively by standard churn drilling. The only recent advance has been the use of larger machines drilling 9-in. holes. This has increased drilling speed somewhat and allowed wider hole spacing, with consequent cost reduction.

Beginning in 1953, tests with a rotary drill were begun and progress since that time has been continuous. Using roller cone bits with tungsten carbide inserts and air flushing, results indicate that drilling rate in most material is three to four times faster than with churn drills. Earlier tests indicated that a heavy duty drill was required to give proper drill pressure and withstand the abuse of hard rock drilling. Bit cost has continued to be a primary problem, but notable advances were made in 1955 by improved bit design, and cost per foot of hole is being steadily reduced. General acceptance of rotary drilling in iron ore mines seems probable.

In the taconite industry, comparative testing of churn drilling, jet piercing, and rotary drilling continues. In the hard, dense taconites, jet piercing has the advantage; whereas, in medium hard rock, rotary drilling is proving competitive, and it now appears

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that both machines will find use. In Michigan, an open pit iron mine operator indicates that while the rotary appears to be satisfactory in the softer phases, bit wear is a major problem in harder rock.

When rotary drilling problems have been solved in the Minnesota taconites, general use of the rotary drill for open pits and quarries seems assured since there are few—if any—rocks now being drilled in this country that are harder to drill than taconite.

Blasting: Early in 1955 a new blasting agent, given the name *Akremite* for its inventor, was made available for open pits and quarries. It was developed over a two-year period by the **Maumee Colleries Co.** and has found wide acceptance because of its low cost. Akremite is a mechanical mixture of commercial grade ammonium nitrate and carbon, which is very insensitive, and hence requires a cap sensitive primer for detonation. It is a free running powder, normally packed in plastic bags containing 50 lb. While its strength is apparently somewhat less than that of other ammonium nitrate powders, due to its packaging, it can be packed in holes so that the weight of powder per foot of rise in the hole will compensate for reduced strength. Cost when loaded, pound for pound, is approximately 60 pct of other ammonium nitrate blasting agents previously used. Greatest limiting factor in the use of Akremite is its lack of water resistance, and while the plastic bag resists dampness, sure protection cannot be provided when it is immersed. For this reason its use is restricted to dry holes or in the upper portion of the explosive column in wet holes where the bottom is loaded to above-water level with water-resistant explosives.

Haulage: In truck haulage the trend continues toward larger units, although smaller trucks are still in use and will be for some time due to space and other limitations. Demand is increasing for trucks with capacities of 30 to 40 tons—with motor horsepowers going up correspondingly. On the majority of new large trucks now being delivered, the torque converter and easy shift semi-automatic transmission are standard.

An interesting development in box design is the application of a 1-in. bottom plate rather than a ½-in. plate formerly used. This substantially prolongs the life of the box bottom and eliminates the need for additional liners or wear bars. For delivery in cold weather operations, most truck boxes are now equipped with box heating facilities as standard equipment.

Extensive experiments continue with regard to off-the-highway tires. A number of mining companies are operating both 5° and 15° taper tubeless tires with highly satisfactory results. Since a high percentage of mine truck tire troubles stem from tube failures, elimination of the tube should prove very beneficial. Tires with extra heavy bodies of 28 to 32 ply all-nylon construction are being tried experimentally, and it is hoped that the heavy tire will take several recaps, thus extending tire life and reducing costs. A tire with a heavy tread containing approximately 50 pct more rubber above the plies than a standard tire is being tried out to give longer original life and protect the carcass for recapping. Nylon has almost completely replaced cotton and rayon in heavy duty tire construction.

New truck types have appeared in the field, and although most mines and quarries employ single axle or tandem axle rear dump trucks, there are several interesting truck-trailer combinations in use, including units powered by engines of 300 to 350 hp with trailer capacities of 35 to 45 tons.

Conveying Systems: Conveying methods and materials have not changed greatly in recent years, but new developments do include the motorized head pulley and flexible two-bearing idler. The load-conforming catenary action of this idler provides excellent belt training. It is light in weight, resilient for smooth support, and self-cleaning, which in some applications is a real advantage over conventional idlers.

Pit skip hoists continue to draw interest as a means of transporting broken ore out of the pit. On Minnesota's Mesabi range four inclined skip systems have been installed where operations will proceed at successively deeper levels until the pit reaches ultimate depth. A typical system has two 20 to 30-ton capacity rockover skips operating in balance on an inclined trackway with a capacity of 1000 tph or more. As the pit is deepened, the dumping point is lowered and the trackway extended.

Tractors and Graders: Tractors and graders are increasing in weight, power, and carrying capacity. Crawler-type tractors are available with satisfactory torque converters, and another innovation is the adaptation of the easy shift transmission in the track-laying tractors. Several new models of heavy duty rubber tire tractors have been introduced in the past year. Grader manufacturers offer their product equipped with torque converters, and one is provided with a converter and easy shift transmission.

Pumping: In pit pumping there have been notable deviations from past drainage practices: 1) elimination of pumpmen through use of automatic or semi-automatic controls (Most companies making the change start the pumps manually and rely on electric controls to stop the pumps and, in cold weather, to drain the lines.), 2) installation of vertically driven pumps where the pumping unit is submerged. These pumps have many desirable features and probably will find a larger market in the future as some of the old split case horizontal pumps are ready for replacement. The submerged type pump mounted on a raft is particularly adaptable to the use of completely automatic controls.

Earthmoving Equipment: Loading equipment has met the demand for greater efficiency by a steady increase in size and speed. Use of light, high-strength alloys wherever possible has permitted an increase in size and capacity without a corresponding increase in weight. As a consequence 40-yd shovels are no longer a novelty in the coal stripping fields; a 60-yd capacity stripping shovel has been constructed; and rumor has it that a 90-yd giant is on the drawing boards. In large size pits and quarries, the demand is for shovels of 6 to 10-yd capacity with sizes generally limited by such factors as crushing capacity, grade of ore, and size of haulage unit.

Cycle speed has been increased through the application of more power coupled with electronic controls. Keeping pace with the trend, consideration has been given to operator comfort and ease of control—larger cabs with improved visibility and heating or cooling as required.

In addition to standard shovels and draglines, developments continue in other types of earthmoving equipment. A wheel excavator in use in several coal stripping projects has demonstrated its ability to move tremendous yardages at low cost. Self-loading wheel scrapers show continued im-

provements in design and increased speed and capacity. Small shovels, draglines, and backhoes are also undergoing a program of improvement, with torque converters now standard equipment for most gas or diesel-powered units. Rubber-tired and crawler-mounted front end shovels are finding increased use as mobile and versatile loading machines. Their ability to dig in confined work areas is a distinct advantage to many operations.

Communication: Short wave radio found increasing acceptance in 1955 as a means of coordinating pit activity. Mounted in foremen's pickups, on locomotives, shovels, and in offices, it has speeded up communication and greatly improved overall efficiency.

The trend is toward larger more productive units for all phases of pit activity. However, the machines must still fit the job and a balance must be reached between the size of the equipment and the work to be done. This will vary with each mine or quarry, and the operator will undoubtedly continue to analyze his work and provide equipment suited to it regardless of trends.

Open Pit Developments

IRON ore continued to hold the spotlight in open pit mining developments for 1955. Minnesota, Michigan, and Canada have projects representing vast expenditures of money and new, often unusual, methods of stripping, mining, and treating ores. The immensity of some of the projects is such that their successful completion will affect not only the economy of immediate areas, but also the entire continent. New methods of exploration such as aeromagnetics and new processes for ore treatment have opened up vast areas in both the U.S. and Canada for future development.

Lake Superior Iron Ranges

Minnesota: Taconite is still the magic word on the Mesabi range, with heavy investments in taconite projects being made by the **Erie Mining Co.**, **Reserve Mining Co.**, and **Oliver Iron Mining Div. of U. S. Steel Corp.**

The Erie Mining Co., operated by **Pickands, Mather & Co.** and jointly owned by **Bethlehem Steel Co.**, **Youngstown Sheet & Tube Co.**, **Interlake Iron Co.**, and **The Steel Co. of Canada Ltd.**, will require an investment of approxmately $300 million and will eventually produce about 7.5 million tons of high grade iron ore pellets annually. The main concentrating and agglomerating plant, located near the mine site near Aurora, Minn., on the eastern end of the Mesabi range, will be the largest concentrator ever built as a single initial unit. Capacity is rated at 70,000 tpd. Finished pellets will be shipped by rail 73 miles to newly constructed dock facilities at Taconite Harbor on the north shore of Lake Superior, 80 miles northeast of Duluth. Development of the two mines and construction of the plant townsite, railroad, and harbor facilities continues at a rapid pace. Initial production and shipment is now scheduled for 1957.

The second full-scale taconite plant now nearing completion is the **E. W. Davis Works** of the **Reserve Mining Co.** located at Silver Bay, about 50 miles northeast of Duluth. This company is owned jointly by the **Armco Steel** and the **Republic Steel** corporations. It differs from the Erie Mining operation in that only primary crushing (in the world's largest gyratory) is done at the mine site on the extreme eastern end of the Mesabi range. The crude ore, all —5-in., is then transported by rail in 85-ton cars to the beneficiating and pelletizing plant at Silver Bay. In October 1955 the first of 12 identical milling circuits was placed in operation, making it the first commercial taconite plant in the U. S. Full-scale operation at the rated capacity of 30,000 tons of crude ore per day is expected during 1956. Annual production should then be on the order of 3.375 million tons of taconite pellet, averaging more than 60 pct Fe.

The third taconite operation on the Mesabi range is the **Oliver Iron Mining Div.** Pilotac and Extaca plants —an operation completing its third year of producing agglomerated taconite concentrates on an experimental basis.

Michigan: The year 1955 marked the first full season's operation of **The Cleveland-Cliffs Iron Co.'s** and the Ford Motor Co.'s Humboldt mine in Michigan's Upper Peninsula. Production at the mine is currently on the order of 250,000 tons per year of Michigan jasper ore. The Humboldt mill, the first one to treat such ore on a commercial scale, is making successful use of froth flotation.

The Republic mine of Cleveland-Cliffs, in a similar type of orebody, is now in the development and plant construction stages with production slated for 1956. Future output is expected to be 500,000 tons annually. The mill is to incorporate several unusual features, namely the use of balling disks and an updraft traveling grate type of sintering machine to produce pellets.

Trends: To maintain a high iron content for furnace charge in spite of a general lowering in grade of Lake Superior ores, increased emphasis on beneficiation techniques continues.

The Oliver Iron Mining Div. of U. S. Steel Corp. recently began operation of its first heavy media plant at the Arcturus mine on the Mesabi range. Other companies already using heavy media are revising and improving flowsheets, building new plants or adding to plants now in operation in an attempt to improve the quality of the product to maintain their competitive position.

Research into the treatment of low grade iron ore and nonmagnetic taconite is being carried on in Minnesota and Michigan. In 1955 Michigan built its first state-supported center devoted to research in low grade ore. This center, located at the Michigan College of Mining and Technology at Houghton, will supplement work being done by mining companies and serve in much the same capacity as the Minnesota Mines Experiment Station.

This year **Jones & Laughlin** ore research laboratory in Michigan announced successful treatment of Michigan low grade iron ores on a laboratory scale by converting nonmagnetic hematite to magnetite and, after fine grinding, making magnetic separation. An increased interest in Minnesota nonmagnetic taconites is also evidenced by several mining companies doing research on the treatment of such ores, and the **U. S. Bureau of Mines** has indicated an intention of working on the problem.

Canadian Iron Deposits

On May 11, 1955 the first shipment of pellets from **Bethlehem Steel Co.'s** Marmora mine was made from the newly built iron ore loading dock at Picton, Ont. Five years of preparation were required to develop this new open pit and mill, located about 65 miles north of Lake Ontario. The ore deposit is a low grade magnetite averaging 37 pct Fe and overlain by some 130 ft of limestone. The ore is magnetically separated and then pelletized into a product averaging about 65 pct Fe. Production at Marmora is currently set at 500,000 tons annually, and present reserves indicate at least 20-year operation.

The **International Nickel Co. of Canada** has begun trial operations on the first unit of the iron ore recovery plant near Sudbury, Ont., and this plant will be on a full-scale commercial operation in 1956. The process used is an Inco-developed method to recover

nickel and iron from nickeliferous pyrrhotite using an atmospheric pressure ammonia leaching process. The plant will eventually be expanded to produce 1 million tons of iron concentrate per year with an average content of 65 pct Fe and less than 2 pct silica.

An engineering project unusual in open pit work is being completed at International Nickel's Frood-Stobie mine. Two vehicular tunnels, one 1800 ft long and the other 400 ft, are being driven in the walls of the pit to take the place of sections of main haul roads. About 5 million tons of ore now tied up in roadways will thus be freed for mining by open pit methods.

Jones & Laughlin Steel Corp. at present is drilling a large magnetic taconite property near Kirkland Lake, Ontario. Original interest in this area was aroused by results of an airborne magnetometer survey. The company has also been diamond drilling magnetic taconite at Bending Lake, Ontario, north of Steep Rock, but drilling has been suspended pending evaluation of the present findings.

Pickands, Mather & Co. recently announced plans for opening the Bristol mine located approximately 45 miles northwest of Ottawa. This property, jointly owned by Pickands, Mather & Co. and The Steel Co. of Canada, contains a low grade magnetite orebody requiring fine grinding, concentration, and agglomeration. It will be operated as an open pit, using standard methods and equipment. Plans now call for construction of a 600,000-ton per year plant in the spring of 1956. The ore will be shipped by rail to the steel mills.

Steep Rock: Steep Rock Iron Mines Ltd. completed ten years of ore production in 1955—a record year with approximatly 2.25 million tons shipped. A major project during the past winter and spring was the moving of two 900-ton hydraulic dredges from the Hogarth mine to orebody *G*, a distance of 2 miles overland. Upon completing the removal of 55 million yd of lake bottom silt from the Hogarth or *A* orebody, the dredges, one after the other, were placed on three large shovel undercarriages and towed approximately 2 miles overland to their new location on the *G* orebody where 53 million yd of silt must be removed.

Caland Ore Co. Ltd., a subsidiary of Inland Steel Co., is dredging lake bed silt from its iron ore property in the Falls Bay area of Steep Rock Lake. This project, the largest of its kind ever undertaken, involves removal of 160 million cu yd of silt to expose for open pit and underground mining an orebody estimated to contain 50 million tons of high grade ore. Dredging began in May 1955, and four years of around-the-clock work will be required for completion with production set for 1960. The two dredges are the largest capacity units ever built, having electric motors of 10,000 hp to drive 36-in. pumps with the booster units on the two pipelines. The project uses 60,000 hp to pump the silt approximately 3 miles over a 300-ft lift to the spoil area. Because of the amount of material handled, this venture is being compared to the construction of the Panama Canal. One big difference is that this job will take less than half the time and use only a fraction as much manpower.

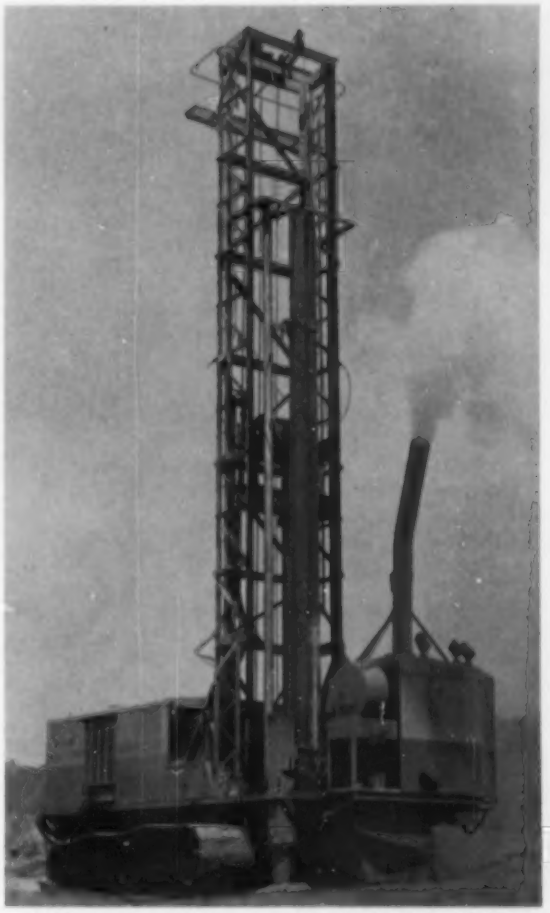
Labrador

The Wabush Lake area of southwest Labrador, leased by **Canadian Javelin Ltd.,** reportedly has more than a billion tons of iron ore, averaging 38 pct Fe, which can be treated and brought up to 65 pct Fe. The main property covers an area of 2300 sq miles. Canadian Javelin is building a railroad line connecting to the Quebec, North Shore & Labrador RR about 40 miles to the east of the Wabush Lake area.

During the 1955 season the **Iron Ore Co. of Canada** began operation in a third open pit two years ahead of schedule. Approximately 8.5 million tons of ore were produced by this company in its first full year of operation.

Other Minerals

North Dakota: The **U. S. Dept. of the Interior** has announced the finding of two large lignite deposits in extreme southwestern North Dakota containing nearly 6 million tons of lignite available for strip mining and suitable for producing electric power. The same department also reported the finding of four smaller deposits.



Advances were made in rotary drills for blasthole drilling. Here a Bucyrus-Erie rotary drill is in operation at a Minnesota iron mine.

Michigan: This year **Inland Steel** celebrated its 25th year as a northern Michigan limestone producer at Port Inland. More than 70 million tons of limestone have been produced at this property making it one of the nation's largest producers. Annual production is now between 4.5 and 5 million tons.

Several steel companies have a financial interest in a new large limestone mine being opened up at Presque Isle.

Nova Scotia: After two years of construction and an investment of $6 million, **National Gypsum Ltd.** has opened up North America's largest gypsum deposit in Nova Scotia, with proved reserves of more than 200 million tons. At a production rate of 2 million tons annually, this will boost the American gypsum supply by 20 pct.

Florida: In April 1955 **E. I. du Pont de Nemours & Co.** placed in operation its new Highland plant near Lawtry, Fla., for recovery of titanium minerals from ancient shore sands. After drilling by water jetting and chopping, the sand is blasted and mined by a dredge employing a cutter head and mounting a 20-in. pump. The ore is pumped to a plant mounted on a barge where concentration is effected by three stages of Humphreys spirals.

Open Pit Mining

Trends in the Western States

New open pit copper mines use truck haulage

Rotary drills on increase—Churn drills with larger bits

by J. C. Van De Water

ONE of the most significant trends in copper mining has been the substantial increase in the number of open pit mines since World War II. Prior to that time there were five producing open pits in the West; today there are 14. While the newer pits are not comparable in size or production, their combined output is a very considerable part of the total copper production of this country.

The initial impetus for this growth came from the severe shortage of copper during the War and the various means used by the Government in the form of loans to stimulate new production. This help from the Government has gradually been withdrawn but the increase in market prices for copper has maintained a favorable atmosphere for continued open pit development.

Few of these new pits would have been economic were it not for the great strides that have been made in cutting operating costs through the development of larger, more efficient mining equipment, particularly heavy duty trucks and bulldozers. There is indeed a sharp contrast between the five older pits and the nine newer ones: in the older pits rail haulage is employed, while trucks are used in the newer ones. This does not mean that trucks have made rail haulage obsolete, but in the new pits few of the orebodies are large enough to justify the initial expenditure for rail equipment and due to size, shape, and location of the orebodies, rail haulage would be all but impossible in most of them.

These nine new pits are widely scattered from Butte on the north to Cananea just over the border in Mexico. Some are conversions from underground to open pits; others have been combined with underground work to recover fringe ore that could not be economically mined by underground methods and some are virgin orebodies, usually known but not previously of economic importance. Reduced mining costs, together with more favorable copper prices, have now made possible the mining of low grade ore that previously was treated as waste. This has greatly increased ore reserves and permits higher stripping ratios. The total effect has been not only to make possible the new pits but also to add measurably to the reserves and life of the older pits.

In discussing this equipment and its use, it should be mentioned that all pit operations follow the same cycle of drilling, blasting, loading, and hauling. The only variation is in the equipment and its use in the different operations of the cycle.

Drilling: The primary object of drilling is to permit the placing of explosives so that the maximum tonnage per foot of hole will be broken consistent with fragmentation requirements. To accomplish this, in all but one pit vertical hole drilling is employed or occasionally a combination of vertical and horizontal drilling or toe holes. At the one exception toe hole drilling is used exclusively, and a remarkable job is being done of breaking approximately 250,000 tpd. This choice of method is governed by lack of accessibility to bench crests for vertical hole drilling equipment and well fractured ground ideally suited to this method. In this operation drilling equipment consists of tractor-mounted 4-in. air drills with long feeds and with each tractor carrying its own compressor, making a compact mobile and completely independent unit.

In the rest of the pits, drilling is done by churn drill, rotary drill, and in one pit in exceptionally hard-to-break ground, 6-in. holes are drilled by piston drills. The churn drill with 9-in. bits has been the workhorse in blasthole drilling for many years. With the advent of larger machines, hole size has been increased to 12 in. at several pits.

As on the Iron ranges, the rotary drill has been a comparative newcomer in blasthole drilling. These

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Miami Copper Co.'s Copper Cities property is one of the Southwest's newer open pit operations. Equipment was moved here from the Castle Dome property when it was shut down.

have been used to drill 7⅞-in. holes at two pits since inception. At other pits, managements, while interested, have been hesitant about changing over due principally to the small size hole. More recently 9 and 12-in. machines have become available and four pits now have at least one rotary on a more or less experimental basis. From all reports, their performances have been very good and it is expected that their use will increase rapidly. Carbide insert bits have not been needed, as the standard steel bits are drilling from 1000 to 2500 ft of hole per bit. Drilling speeds appear to be at least three times that of churn drills in like ground.

Originally the rotaries came out with mechanical dust collectors but these have been discarded and water introduced in the air streams, for dust control. The latter has proved simpler and more efficient in controlling dust and has eliminated the bulky dust collectors. Manufacturers are now supplying water injection as standard equipment.

The rotaries have one disadvantage: they are not very mobile. This is a serious fault, as their high production results in many more time-consuming moves than were necessary for the less productive churn drill.

Blasting: Few changes have been made in blasting practices, and the explosives generally in use are the various gelatin dynamites and free running bag powders. Nevertheless, powder new to the West is undergoing trials at the present time. This is the Akremite powder previously discussed in Eastern Trends. (See page 163.)

Detonating fuse is standard practice with a single trunk line and one or two lines down the holes, depending on the operation's past experience and on confidence in the fuse. A double line is used at most pits.

At several pits experimentation has been conducted with millisecond delays, but the advantages seem small and the practice has not received wide acceptance.

Loading: In this field there have been no basic changes in shovels. Where the 5-yd unit had been standard equipment for many years, the use of 6, 7, 8, and 10-yd machines is now gaining favor. The shovel field is becoming more competitive and improvements such as magnetic clutches, electronic controls, and pressurized cabs are adding to general efficiencies.

Haulage: Rail equipment has had no basic changes, the trend being to larger, heavier equipment both in locomotives, ore and waste cars and rail sizes.

Control of train movements has been greatly improved by the installation of central traffic control systems. This has eliminated most switch tenders and added greatly to train efficiencies by putting most of the rail traffic directly under the control of one man.

While truck haulage cannot compete costwise with rail on long hauls, it can more than hold its own on distances up to a figure somewhere between one and two miles—and if grades over 3 pct are in the picture, the break-even point between trucks and rail is still further extended. Aside from this, trucks offer greater versatility, permit highly selective mining and much shorter working faces. All these features are of great importance in the smaller pits.

As to the trucks themselves, they range in sizes from 15 to 50 tons and from 150 to 600 hp. In 14

Kennecott's newest pit, the Veteran. This pit will eventually be the second largest pit of the Nevada Mines Div. When completed it will be nearly 2500 ft long, 1500 ft wide, and 850 ft maximum depth.

years they have progressed from 150-hp engines with chain drives to torque converters, automatic transmissions, torquamatic brakes, power steering, and turbocharged engines.

The trend as far as size goes is not at all clear. The 30 and 34-ton units are the most popular, but while some operators feel that the larger the better, as long as maneuverability is not lost, others do the bulk of their hauling with 22-ton units. These latter units in most cases have been built up and reinforced to handle 30 tons or more so that actually there are few 22-ton trucks working near that load limit.

Aside from the standard rear dump trucks, there is the rear dump trailer tractor combination that shows some promise of low maintenance costs. As yet there are not enough of these units in use to prove anything, but they will bear watching.

Bulldozers: While the bulldozer has no place in the operating cycle, it is one of the most vital pieces of equipment in the pits. Building rail grades and haul roads, tending waste dumps, cleaning shovel pits, pioneering, and performing countless other jobs, this versatile piece of equipment is in a class with the heavy duty trucks in importance to the newer pits. Here, too, the trend is to heavier equipment, more horsepower, torque converters, and automatic transmissions.

Some newer entries in the dozer field are the lighter rubber-tired units. Their greater speed and maneuverability have brought about a degree of specialization by assigning the cleanup of shovel pits, roads, and dumps to these units, thus freeing the track mounted dozers for the heavier work. The selection of machines in the rubber-tired category is limited, but others will be available in the future.

New mobile compressor-drill unit at Bingham Canyon, Utah.

Operators: The heart of the whole open pit operation is the individual workman on the job, for within the work limits of any piece of equipment, the difference between good and poor performance is in the hands of the operator. Because of this, employers are trying by educational means to create job attitudes that will encourage men to perform their particular part of the operation as efficiently as possible. Some progress is being made toward these goals by employe training programs and improved communications between the man on the job through his supervisor to top management and back to the man. Employe questions and problems that were ignored before are being answered. Company policies are being formulated, explained, and adhered to. Training is a long-range and continuing program, and if it is properly applied, there can be little doubt of its ultimate success and benefit to employe and employer alike.

Methods Improvement: Industrial engineering has entered the mining picture in the last few years. To date, attention has been directed toward studies of maintenance methods, supplies, and equipment. Results have been very gratifying and point toward a much wider scope as the program continues.

Since all open pit mining is essentially the same as far as method goes, the changes and improvements are mainly due to improved equipment and improved performance of equipment; consequently, the trend of open pit mining will follow the trend of equipment design. These trends are being shaped toward two objectives—higher productivity and a decrease in operator fatigue and hazard. Many improvements have been made and many more are still to come.

MINING GEOLOGY IN 1955

by Charles Meyer

THE year 1955 was a busy one for mining geologists, for the expanding world-wide business activity kept the demand for mining products generally high, stimulating operators to develop local ore reserves and to expand their efforts to find new deposits.

The uranium rush was still on, although probably past its maximum rate of climb. Prospecting was also stimulated by the increasing demand for rare metals, and this created new and fascinating targets for exploration. On the whole, it was a boom year when the prospector's chronic optimism found few repressions.

It was also a year in which this optimism was rewarded, for major discoveries, such as the Indio Muerto deposit in Chile, were made as the result of imaginative geological and geophysical investigation. With exploration so highly competitive, the details of the application of both tools are, for the most part, closely guarded secrets. Yet it is possible to estimate what geological factors may have been found profitable and how they have been applied, while at the same time scanning the broader field of geological research for 1955 and speculating as to its future applicability in mineral exploration.

Structural Studies: Traditional emphasis on structural control of ore localization still occupies most mining geologists, and it is likely that this point of emphasis will retain first place among the methods of mining geology, at least as generally applied to epigenetic ores. Although an empirically observed structural pattern in a given district may often serve a useful purpose without attempts being made to understand its genesis, maximum benefit can be derived only if the pattern can be extended through interpretations of its formation. This is particularly true when structural theory must be applied in the examination of a new, poorly exposed prospect.

A milestone in understanding the development of fracture patterns was passed during 1955 with the completion of E. H. Wisser's forthcoming *Memoir* of the **Geological Society of America,** *Ore Deposits and Doming in the North American Cordillera.* Wisser discusses individually the structural developments of numerous important districts and relates these individual patterns to the development of doming in the Cordillera.

Additional experimental evidence on fracture patterns associated with doming was presented by Ernst Cloos in his presidential address published in the *Bulletin* of the **Geological Society of America** during 1955. *Economic Geology's 50th Anniversary Volume, 1955,* promises an encompassing summary of the general geological relations that are still the core of our knowledge about ore deposits.

The **U. S. Geological Survey** continues its traditional series of investigations into the general geological and structural settings of mineral deposits. This is of tremendous importance to industrial advance, and T. B. Nolan reports that during 1955 the

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USGS completed or was nearing completion of its intensive studies in the following districts: Tri-State lead-zinc district; Little Dragoon Mountains, Ariz.; Central district, N. M.; Darwin area, Calif.; Holden area, Wash.; Metalline district, Wash.; and Bishop Tungsten district, Calif. Nolan also points out that a major district study in behalf of the AEC is almost completed in Gilpin and Clear Creek counties in the Colorado Front Range. Work is in progress in more than 30 other metal and nonmetal mining districts, excluding the Colorado Plateau. Four professional papers and 28 bulletins important to mining geologists were published during 1955 as well as numerous quadrangle and mineral investigation maps.

Survey geologists also contributed a number of significant structural papers to the journals during 1955. In *Economic Geology* F. S. Simons describes an interesting case from Chilebe lead-zinc-silver district in northern Peru where vein intersections are not favorable loci for ore deposition, a condition somewhat analagous to parts of Butte.

In the latest of the fine series of papers on the **Santa Rita area, N. M.**, Kennecott geologists Ordonez, Baltosser, and Martin contrast the nature and mineral content of the geologic structures surrounding the Santa Rita intrusive with those of Fiero-Hanover and Copper Flat intrusives. They emphasize that the emplacement of the Santa Rita stock seems to have been a passive one followed by downward readjustment in the north end of the mass, whereas the other two pushed or thrust the sediments aside. They make the interesting suggestion that these differences may account, in part, for the shattering of the Santa Rita porphyry and possibly its mineralization with copper, although they do not propose a mechanism for this apparently anomalous behavior.

G. M. Schwartz reports that through a fellowship grant from the Reserve Mining Co., the **Minnesota Geological Survey** is undertaking a fundamental investigation of the mineralogy, petrology, and stratigraphy of the taconite in the eastern Mesabi district. Thesis work at universities shows a quickening interest in mining geology among students. Of course, the work mentioned is a small fraction of the total volume of top-notch structural geology done every day by company geologists, and there is a perpetual lament that more of this does not find its way into the literature.

Mapping: Careful mapping of igneous, sedimentary, and metamorphic rock patterns, and wall-rock alteration patterns, has also been progressing through 1955. A particularly commendable job is the one the USGS, with M. R. Klepper in charge, has had in progress in the **Boulder Batholith of Montana.** Here a persistently detailed job has been done that will be an immense contribution to understanding why Butte is where it is and why no other base metal district of the Batholith is a "Butte." Klepper and others will report on late magmatic effects in the Boulder Batholith at the coming February meeting of AIME.

Great strides were made during 1955 in using aerial photography to prepare topographic base maps and geological maps. Most mining companies now precede regional or even district-wide geological studies with a good aerial photographic job if none already exists, and use of colored photos in reconnaissance is expanding.

A report by E. L. Ohle from **St. Joseph Lead Co.** in southeastern Missouri states that careful mapping of sedimentary features such as facies variations and algal reefs in the Bonneterre formation has improved the company's prospecting efficiency and planning for mine development. St. Joe geologists are also accumulating permeability data on the various rock types through laboratory measurements of flow through drill cores, and the company is cooperating with the **Lamont Laboratories** and the **Geological Society of America** in a study of lead isotopes and their distribution.

Also on the *isotope* front, mining geologists in general should be aware of the possibilities of *absolute* age-dating of K-bearing mineral phases through the K_m-A_m method. Any mineral containing potash—feldspars, micas, etc.—is theoretically susceptible to the method. Different minerals in the same rock give different results, but similar minerals in different rocks are presumably comparable. Disparities are evidently due to different rates of leakage of the Argon. Here is a method that can be applied successfully, for example, to distinguish relative ages of the potash minerals in several igneous rocks whose contact relations are obscured. It can be used to correlate extrusives or to suggest which of many igneous rocks in an area is most closely related in age to a period of mineralization. It will also help decide, on a regional basis, which intrusives belong to a known metallogenic epoch. The possibilities are enormous.

J. K. Gustafson of **M. A. Hanna Co.** calls attention to a detailed job of mapping by geologists of the **Iron Ore Co. of Canada** in its open pits in Labrador-Quebec. Here A. E. Moss and his assistants have found that different stratigraphic layers in the iron formation yield different types of ore. Thus close mapping of ore types assists in unraveling the tightly folded and faulted structures, which in turn help in extending orebodies.

It is scarcely necessary to call attention to work of the USGS in unraveling detailed stratigraphic features such as stream patterns in the **Colorado Plateau.** However, it is important to mention the special uranium issue of *Economic Geology*, where numerous summary reports appear concerning ore controls. Certainly no simple syngenetic or epigenetic origin has yet emerged as satisfying to all comers. One thing is certain, the pressure to find uranium has launched an all-out geological effort that has paid off handsomely in uranium found. More than likely, part of this success is attributable to the very disagreement on the theory of ore deposition which itself stimulates more and greater attention to observation of details which in turn leads to more ore.

Alteration Studies: Published studies of hydrothermal alteration in 1955 lead off with the description of "Hydrothermal Alteration at the Climax Molybdenum Deposit" by John Vanderwilt and Robert U. King in MINING ENGINEERING for January 1955. They point out that "orthoclase with quartz predominates over sericite-argillic alteration where the greatest concentration of molybdenite occurs. The closing phase of alteration was marked by quartz, pyrite, topaz, sericite, and argillic minerals." They compare these features and others to attributes of the porphyry copper deposits.

Peter Price reports from **Noranda** that alteration studies begun in 1947 are progressing satisfactorily. Price makes the very appropriate comment regarding alteration that people too often "squeeze other

A diamond drill location close to the discovery site of the Indio Muerto copper project in Chile.

districts into the same theoretical bottle that they have applied to areas with which they are more familiar."

Mineralogical research on alteration minerals advanced substantially during 1955. Interest in the alkali-feldspars still flourishes. The groups at the **Geophysical Laboratory** and at the **University of Chicago** have written most of the papers on feldspars in recent years. W. S. MacKenzie and J. V. Smith contributed during 1955 a routine X-ray method for the study of alkali feldspars and applied the method to study of the orthoclase microperthites. Both papers are in *American Mineralogist*. The distribution patterns of low and high temperature ordered-disordered Na-K feldspars, indigenous or introduced, would be intensely interesting and perhaps highly significant in studies of ore deposits where feldspars figure importantly in ore genesis—in some of the porphyry coppers, for example. Lester Zeihen and Paul Cloke have begun such studies in **Anaconda's Geological Research Laboratory**.

The clay minerals have been the subject of several national conferences sponsored by the **Clay Committee** of the **National Research Council**. The proceedings of two of these meetings have been published during 1955, one by the **California Div. of Mines** as *Bull. 169*, the other by **National Academy of Sciences** as *Publication No. 327*. These papers and others are summarized by Ralph E. Grim in *Economic Geology's 50th Anniversary Volume*. Mineralogical studies of natural micas have been reported in *American Mineralogist* and *American Journal of Science* by E. W. Heinrich and others at the University of Michigan. H. S. Yoder and associates at the **Geophysical Laboratory** have conducted important experimental studies delimiting stability fields of certain of the micas. The most recent of Yoder's papers, scheduled for the December issue of *Geochemica et Cosmochimica Acta*, treats the field of mica stability in the presence of quartz, an important phase in ore deposits. A third main group of alteration minerals—the chlorites—remained tough enough to discourage all but the very hardiest mineralogists during 1955.

In epigenetic base metal deposits, variations in the mica and micalike clay minerals appear to be a promising field that is now being explored more fully. Well coordinated field-laboratory studies of alteration are still too few, though their number is mounting slowly.

Sulfide Mineral Studies: Experimental studies of sulfide mineral phases at elevated temperatures and pressures are difficult, but they are worth their weight in gold for debunking naive interpretations concerning apparent sequence of minerals in polished surfaces. Normally there are tough problems along the interpretative path from apparent sequence of mineral phases to order of introduction of metals into an orebody. Some of these problems are:

1) Evaluation of the geometrical configuration between two mineral phases, as to which is apparently replacing the other across a mutual interface. Here it is well to remember that the only compelling evidence for replacement is retention of a definitely inherited shape or structure. Yet any pattern could be the result of replacement. An explanation as omnipotent as this should be used with caution rather than abandon.

2) After the sequence is decided, does it apply to the original order of introduction of the mineral ingredients into an orebody; to the introduction of the last phases only, which reacted with earlier phases in the solid state; or to the introduction of none of them but merely to the order of appearance of currently observed phases during post-depositional changing environments of temperature, pressure, and activities or concentrations? Again there is probably no unique answer to those questions in the face of knowledge about the relatively rapid diffusion rates among metal ions in sulfides, especially in view of the complicated thermal and chemical histories of many orebodies between aggregation and extraction.

Ambiguities of textures are in themselves frustrating, but even after the second group of questions is answered for a given case of an epigenetic ore, there remain problems of whether the supposed order of fixation at a given point or in a given zone relates to the order of separation *from* the source of the metals, or whether it is merely order of precipitation *at* the point of reference. And in the latter case it is necessary to distinguish between order of deposition *at* the fixed point and order of deposition *from* a moving increment of solution. Assuming equilibrium is not attained, and progressive thermal and chemical insulation at the point of reference, the much discussed reverse order of standard sequence in relation to solubilities is not anomalous but to be expected.

Application of laboratory studies of ores and ore-forming theory to mining geological practice has been handicapped by inadequate appraisal of these problems. It is the process of aggregation of ore ingredients into an orebody that is most important for the practicing mining geologist. At this stage each deposit is probably best treated as a problem in itself where careful integration is advantageous between hypothesis concerning mineral sequence and all the other factors of geologic background. Such considerations should receive impetus from the publication of the new edition of A. B. Edwards' *Textures of the Ore Minerals*, published by the **Australasian Society of Mining & Metallurgy**. Most welcome is the careful accumulation of sequence data such as that described by J. E. Harrison from the **Freeland-Lamartine District, Colorado**, *(Economic Geology)* where veins of galena and sphalerite cut veins of quartz, and sulfide minerals. Even

URANIUM discoveries such as the Happy Jack mine, shown in upper center of this photo, have stimulated intense geologic study in the Colorado Plateau area and surrounding states. Geologists are far from agreed as to theories of deposition, but classic geologic study has delineated the most promising formations for finding ore. Attention to detail is important.

in the latter case it may be possible to postulate selective remobilization of the sulfide phases. Rigorous experimental analysis of sulfide chemistry is still very much in order.

Geochemistry and Geochemical Prospecting: Both have moved ahead rapidly in 1955. Methods and equipment for rapid acquisition of quantitative and semiquantitative data are now reaching the stage of development where tremendous volumes of information will become available. It is to be hoped that digestion processes, i.e., integration of the data with general geologic background, can keep pace. Three types of information of interest to mining geologists are coming out under the heading of geochemistry: 1) investigation of the physical chemistry of geologically interesting systems, 2) crystal chemical studies and the distribution of trace and minor elements, and 3) geochemical prospecting—the analytical procedures for determining distribution of the target metals themselves.

G. C. Kennedy, H. S. Yoder, and R. M. Garrels each contributed important papers relating to chemistry of ore generative processes. Kennedy and Yoder discuss the distribution of that important ore solvent, H_2O, in certain magmas and metamorphic rocks, respectively, in *Special Paper 62* of the **Geological Society of America**. Kennedy postulates conditions under which concentrations of water would take place in the upper and outer portions of igneous stocks and draws attention to possible applications in porphyry copper development. Yoder treats the expulsions of water from shaley sediments when they are subjected to metamorphism of the silicate phases.

A paper by De Vore in the March issue of *Journal of Geology* applied crystal chemistry in the evaluation of adsorption in fractionation and distribution of elements. In a statement evaluating differences of behavior of certain ore metals during metamorphism, De Vore points out that fractionation and distribution should depend in large measure on how the metals are bonded in and on the silicates. The chief minerals involved are the mafics, hornblende and biotite. De Vore says that transformation of a hornblendite from the epidote-amphibolite facies into a hornblendite in the granulite facies would be accompanied by a release of large amounts of Cu, Cr, and Ni among other elements. The reverse transformation (retrograde) would liberate Pb, Zn, Ti, Mn, and Fe. A transformation of biotite to hornblende would liberate Co, Cr, Ni, Cu, and Zn regardless of the metamorphic facies. The quantities of material thus liberated are eye-openers, e.g., 4 million tons of NiO per cu km. On the other hand, Dennis Shaw reports in the *Bulletin* of the **Geological Society of America** that concentration of most elements remains constant during regional metamorphism of pelitic rocks. Ni and Cu show slight decrease, but Pb and Li indicate well defined increases. Presumably sulfur would be happy to get out with the water, if and when the water gets out. In this connection, it would be interesting to know the effect of NaCl (presumably high in connate waters) on the solubilities (or transportability) of silica and the sulfides, for this may be among the factors that determine whether or not specific metals leave sedimentary rocks during metamorphism before melting takes place. Adequate evaluation of the efficacy of metamorphism as an ore generative mechanism awaits detailed geological and geochemical work in favorable regions.

Distribution of trace element content has been undertaken by Wayne Burnham and others under the direction of J. S. Noble and sponsorship of **Kennecott Copper Corp.** Noble reports that the project "is aimed at delineation of metallogenic provinces, and within those, ore-forming channelways, by a study of the distribution of trace elements in sulfides. In this program, a regional study of the southwestern states and adjacent areas has been completed, and more or less detailed studies of smaller areas are now in progress." James Boyd, vice president-exploration, for Kennecott, points out that the project is conceived as foundation rather than applied research, although it may eventually be of considerable value to mineral exploration.

The very extensive geochemical exploration program undertaken by the USGS was well summarized

by T. S. Lovering in MINING ENGINEERING for October. Lovering discusses the pitfalls as well as the advantages of geochemical work. Certainly the methods have obvious possibilities of application in areas where soil, sediment, or glacial cover is relatively thin but nonetheless obscures surface geology. In areas where bedrock is exposed and the target is more specifically a buried orebody that must be located by means of what Lovering calls its "outlet" channel, the problem becomes more difficult, and geochemical *smoke* currently is as subject to problems of evaluation as any other kind of *smoke*.

As reported by David Williams, the **Royal School of Mines** in London is conducting an energetic program of geochemical research and participation in geochemical exploration programs in Northern and Southern Rhodesia, Sierra Leone, and Uganda. In Northern Rhodesia, in cooperation with the **Rhodesian Selection Trust (Services) Ltd.**, "extensive field work on the application of systematic soil sampling has been carried out and laboratories have been completed during the present year. The results were extremely satisfactory and the field methods have now been used by the company with marked success." In Sierra Leone an effort is being made to delineate buried kimberlite pipes by soil sampling. Base and rare metal deposits are the targets in Uganda, and gold and chrome in Southern Rhodesia. Obviously a very enthusiastic geochemical unit is functioning with noteworthy success.

The use of geochemical methods in tracing geologic structures and stratigraphic units was reported by F. S. Robertson at last year's Chicago meeting. The work was done by the **Montana Bureau of Mines and Geology.**

In addition to the direct application for ore search in covered areas, geochemical exploration's great dividends may come from better appreciation of minor element distribution from a viewpoint of regional zoning. It may ultimately contribute substantially to the understanding of why ore is where it is and what the mechanisms are for accumulation and transfer of the metals.

Analytical tools, for trace element work and for ordinary analytical methods, are advancing phenomenally. The USGS completed a truck-mounted spectrographic laboratory in 1955. The unit is capable of making quantitative and semiquantitative determinations for more than 30 elements in the field.

Flame spectrophotometry in conjunction with colorimetric work now also eliminates much of the tedium from analytical schemes for silicate rocks on a routine basis with accuracies within the normal sampling error. And X-ray fluorescence now also challenges nearly all comers for many elements. Special techniques have been developed by which even grains of mineral in thin sections and polished sections can be analyzed semiquantitatively, and X-ray fluorescence even threatens to take over routine metal assaying.

It is reported by Jane E. Erikson that the **Geochemical Exploration Section of USGS** now "conducts a training course for interested chemists and geologists from private industry who have a need for instruction in the laboratory and field techniques used in geochemical prospecting. During the year the Section trained about 15 geologists and 25 chemists in the laboratory at the Federal Center in Denver."

In Retrospect: Mining geology did not change radically during 1955. No tool has yet been devised to eliminate geological judgment from the prospecting equation. Careful imaginatively systematic mapping of every variable that can be seen still precedes the most successful evaluations of new properties. As pointed out by the **National Science Foundation's Subcommittee for Geological Research** in 1955, the time for thorough examination of all aspects of the geology of the operating districts is now, before many of the world's major deposits have most of the geology mined out of them! This is not an idle recommendation. Its validity is demonstrated by a brief case history which reached fruition during 1955. **Indio Muerto,*** Anaconda's extensive new disseminated copper property near Potrerillos, Chile, is an outstanding case where a major new mine discovery is due to an aggressive exploration policy based on sound geology. For years the Anaconda team of geologists have been studying the disseminated copper deposits from all possible viewpoints, trying to evaluate the many types of targets that may be encountered. V. D. Perry describes the Indio Muerto success:

"The steep slopes of Indio Muerto peak were examined in February 1950 by V. D. Perry, chief geologist, Anaconda, and W. H. Swayne, exploration geologist for Anaconda in South America. An excerpt from the field notes of that trip records the following observation: 'Hard siliceous ridges of quartz porphyry form crescentic patterns indicating ring-like intrusives. Inside these rings there are large areas of weak copper stain with intermediate crescentic shaped zones of iron oxide seams, abundant quartz veinlets, and considerable sericite and kaolin alteration . . . to indicate the presence of pyritic mineralization with some chance for secondary chalcocite enrichment. Further mapping . . . is well justified.'

"Systematic field mapping by Swayne, including detailed studies of structures, patterns of distribution of rock types, and zones of alteration, was supplemented by petrographic studies at the company's geological research laboratory at Butte, Montana. Several drilling targets were outlined and actual exploratory work was started in 1952. There was some preliminary success under copper showings several kilometers north of Indio Muerto and, after a number of 'teaser' holes, geologic effort and persistence in keeping the drills going on different kinds of targets finally paid off. In 1955 good ore was struck below the oxidized zone in Turquoise Gulch within the shadow of Indio Muerto peak. To date the best ore has been developed in a secondary enrichment blanket confined to a ring of intrusive porphyry and related mineralized fractures; ore of a primary nature is also inferred but the drilling has not progressed far enough to predict probable ultimate tonnages."

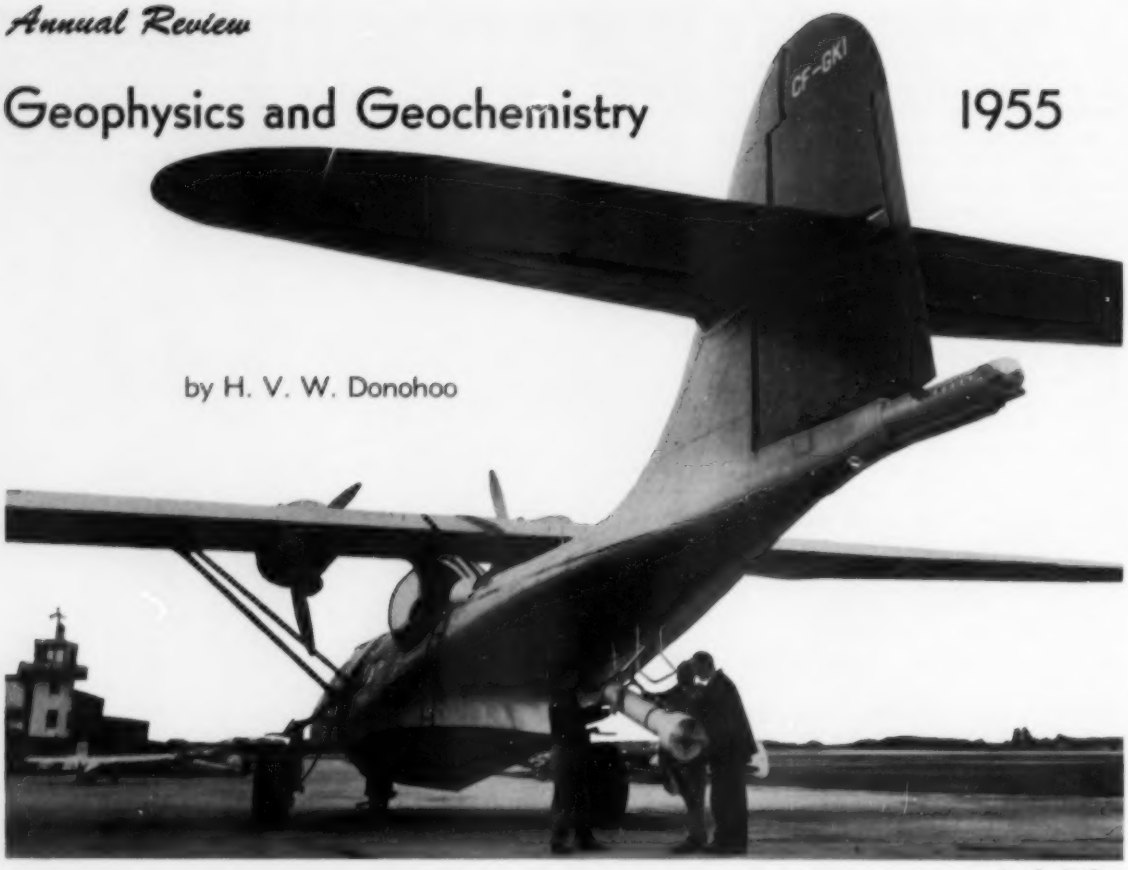
Anaconda's announcement during 1955 of its new copper orebody at Indio Muerto should be a source of great satisfaction for its geologists and managers who participated in the exploration. The result of applying detailed geology to the successful search for a new porphyry copper deposit should be another "morale booster" for other mining geologists to "go and do likewise."

* See frontispiece page 169—Indio Muerto Peak, near Potrerillos, Chile. Torquoise Gulch is behind the spur running from the top of the peak to the right edge of the photograph.

Annual Review

Geophysics and Geochemistry 1955

by H. V. W. Donohoo



Aero Service Corp.

- **Increased use of Geophysics and Geochemistry in mining**
- **Airborne electromagnetic surveys extensive in Canada**
- **Aeromagnetic surveys remain most widely used method**
- **New portable ground magnetic surveying equipment**

EXPLORATION in 1955 was marked by a trend toward large-scale programs using a number of geophysical techniques. These programs were initiated both to locate new mineral districts and to bring individual prospects into production.

All 14 companies replying to the author's questionnaire include geophysics in the general exploration routine whenever it is applicable, and five companies carry on extensive geophysical programs. Nearly all report that company personnel perform the surveys. In addition to these firms there are the many smaller operators who contract much of their geophysical work. There are indications that the volume of such contracting is sizable.

Airborne surveys, magnetic, electromagnetic, and radiation surveys, continue to be almost exclusively the field of the contractor. Initial investment for aircraft and equipment, as well as maintenance and special personnel costs, has made it impractical for a single company to operate such crews. The flying contractor has demonstrated that he can furnish these services more efficiently and cheaply, although a number of operators, both large and small, believe that air surveys can be conducted on a less elaborate basis than that generally provided by the contractors. Reconnaissance ideas may not justify an elaborate mapping contract. The need is for efficient

This review has been prepared not only to give the practicing mining geophysicist a thumbnail sketch of current developments in geophysical instruments and techniques and news of world activity, but more particularly, it is phrased to inform management personnel. The tremendous activity indicated here is a result of management decisions. Continuing activity will again be based on management's evaluation of the results produced and the promise indicated.

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methods of screening unknown territory for prospects that have enough promise to justify larger expenditures for detailed surveys. One of the smaller operators has expressed the desire that reconnaissance-type instruments be developed which can be purchased by individual companies and used with small chartered aircraft. New developments in electronic instrumentation and miniaturization may soon make this scheme realizable.

The most important question management asks concerning geophysics or any other activity is: *Do resulting discoveries justify the cost?* The answers obtained here were by no means unanimous. Those who used magnetic and radiation surveys in direct prospecting seem to feel that the work paid for itself almost immediately. Where less direct techniques are used, the answers are more ambiguous. Some noted that certain methods, although helpful, were too expensive. The cautious viewpoint was expressed that although successes are indeterminate at this time, there is hope that the pay-off will come over the long period. Others justify this by pointing to indirect values obtained in eliminating barren areas and in providing valuable leads for other discovery techniques. The overall answer may be revealed by the rapid increase in use of geophysics in mining and the discoveries now being made.

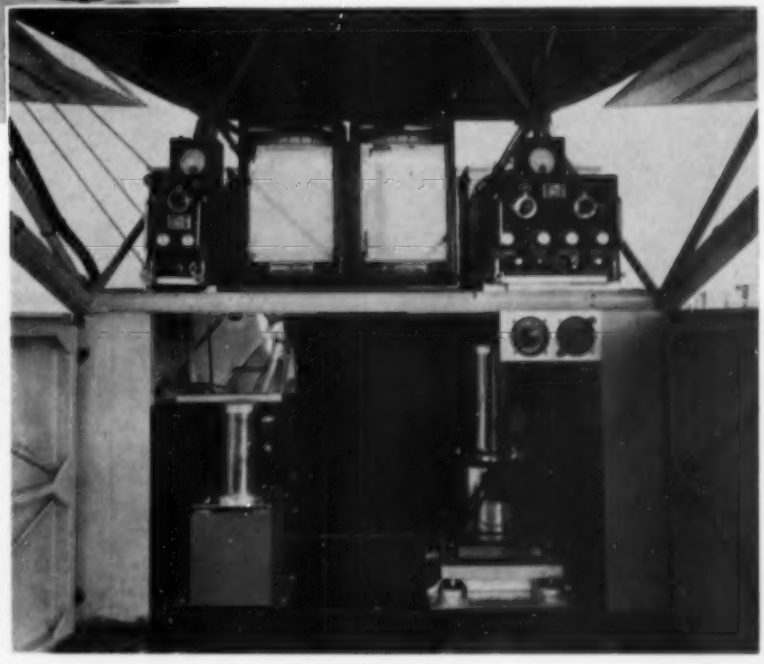
All groups questioned believed that more trained geophysicists are needed for the mining industry (see **Education**). Principal concern is for supervisory personnel. It is noted that training of geophysicists varies widely but that there is a definite lack in mathematics and physics. Most groups feel that the geophysicist's work must be carefully integrated with that of the geologist, as some geophysicists are said to be too specialized in relation to overall exploration objectives and problems. The problem of personnel seems to be much more acute in countries other than the U. S. and Canada, since most foreign universities do not attempt to train specialists in this field.

It will be noted below that Government work in geophysics during 1955 has been extensive and important. It is commonly maintained by governments that theirs is a function of service, in no case to compete with private enterprise. Consequently their programs can be classed either as research or development research.

Airborne Electromagnetic Surveys

The promise of interest in airborne electromagnetic equipment and surveys made in this Review last year has been fulfilled, at least north of the Canadian border. All year, rumors of vast surveys and important discoveries have drifted southward, and air surveying contractors have been engaged in a flurry of activity to obtain licenses to make services more readily available to operators in the U. S. Two Canadian contractors have reported flying a total of 80,000 line miles of survey, mostly in Canada, which in itself indicates big prospecting business. The method seems particularly helpful in locating conducting sulfide zones, and petroleum applications have been noted, but details on actual problems solved and orebodies discovered are still to be reported.

Aeromagnetic Surveys Ltd. and **Lundberg Explorations** state in professional papers that they have successful and practical equipment. **Hycon Aerial Surveys** has announced the licensing of



ABOVE: The engine on this Consolidated Vultee L-13 was raised from 245 to 450 hp to give better high altitude performance and improve flexibility and safety in prospecting. RIGHT: Mt. Sopris Instrument Corp. radiation detection equipment shown at rear of cabin includes two scintillators, one with a 3-in. crystal for uranium prospecting, the other with a 5-in. crystal used experimentally for oil exploration and also for uranium. Also shown are two synchronized recorders. One of the recorders plots absolute altitude above ground and the other can be connected to either of the scintillators.

equipment for use in the U. S., and **Fairchild Aerial Surveys** and **Aero Service Corp.** have similar plans. **Bear Creek Mining Co.**, **Dominion Gulf Co.**, and **Mindamar Metals Corp.** report having contracted surveys during 1955.

In the Lundberg system, recordings are made of secondary fields created either by using inductive stimulation directly from the plane carrying the recording devices or by energizing the ground by means of very long, grounded cables. They report 4200 sq miles of survey in northern Europe and 450 sq miles in North America. The Aeromagnetic Surveys Ltd. equipment utilizes a two-frequency, horizontal transmitting coil draped over the plane and a pickup coil towed at the end of a cable. Company reports flying 75,000 line miles of electromagnetic survey in Canada during 1955. Aeromagnetic Surveys Ltd. is also developing a lightweight, single-frequency system measuring both in-phase and out-of-phase components of the secondary field for use with a light helicopter.

A number of unidentified groups appear to be conducting research and instrument development on airborne electromagnetic systems. Model experiments are reported by the **University of Western Ontario**, the **Geological Survey of Finland**, and **Bear Creek Mining Co.** Aeromagnetic Surveys is studying the interpretation of some 50 individual surveys. Experience to date indicates that 85 pct of the airborne anomalies are confirmed by subsequent ground electromagnetic surveys; the remainder are apparently regional-type anomalies.

Aeromagnetic Surveys

Despite a reported decline in number of total miles flown during 1955, aeromagnetic surveys continued to be the most important and widely used mining geophysical method. They are frequently used, especially in Canada, to precede field work for outlining regional structure and delineating areas to be prospected. Aeromagnetic surveys occasionally follow some geologic reconnaissance work on the ground to locate extensions of known structural and mineral trends. They have been used more or less for direct prospecting in the search for iron orebodies. In all these procedures, however, anomalies are selected for additional ground geophysical work before drill sites are chosen. Most frequently ground magnetic surveys are made to provide more definite data, although geochemical surveys are also becoming popular for follow-up work.

The helicopter has been suggested as a vehicle for low flying surveys. Although the time required to complete a helicopter survey is comparable to that with fixed-wing aircraft, the costs approach those of a ground survey. Evidently the principal trouble with helicopter surveys is to obtain an aircraft capable of carrying the equipment load at altitudes above 6000 ft that can be operated at reasonable costs. Better helicopters and miniature magnetometer equipment are in the process of development. Bell aircraft has recently developed a new model which is said to operate efficiently and safely on surveys up to 16,000 ft above sea level.

Agocs of **Aero Service Corp.** has described a magnetometer survey in the Green Pond area of New Jersey in which data obtained using both a fixed-wing aircraft and a helicopter are compared with ground magnetic and geologic information. The helicopter map is definitely the more diagnostic. Another such survey, also by Aero Service Corp., was flown in southern Utah in 1955. Surface anomalies were minimized with the detector at 75 ft above the ground. Although flight characteristics of the helicopter used were marginal at 6000 ft, the survey was considered successful.

The Gulf magnetic gradiometer reported last year was used experimentally by **Columbia-Geneva Steel** as an auxiliary instrument on an iron ore survey in 1954. It was concluded that for this application, its use is probably not justified. Glicken has reported on this instrument in MINING ENGINEERING, November 1955, page 1054.

The Varian nuclear precession magnetometer, developed last year, has been successfully installed in a fixed-wing aircraft, and **Hycon Aerial Surveys**, which holds the license, has used it to survey commercially several areas in Western U. S. Data are comparable to those obtained with flux-gate type instruments. A proposed improved design to utilize punched tapes for recording should reduce the labor of compilation.

Aeromagnetic survey coverage flown throughout the world during 1955 by both Government and mining groups approaches 200,000 sq miles, and the reporting is by no means complete. **Gordon Minerals**, **Dominion Gulf**, **Columbia-Geneva Steel**, and **Bear Creek** all report having made surveys. Of the contracting firms, **Fairchild** flew 18,000 line miles in 24 separate areas throughout the world for mining companies; **Lundberg** has flown a total of 25,000 sq miles in Europe, North America, and Africa; and **Aeromagnetic Surveys** has flown a total of 108,000 line miles in Canada and the British West Indies. These last two figures may include some petroleum work, and all three include some simultaneous radiation and/or electromagnetic data recording.

Government agencies were again active in aeromagnetic work. L. W. Morley has reported on the work of the Geophysics Div. of the **Geological Survey of Canada.** Two areas were flown in 1955. The Queen Elizabeth Islands, in the Arctic region, were flown in a very loosely spaced, cobweb pattern working out from the RCAF base at Resolute Bay, Cornwallis Island. Approximately 7000 line miles of magnetometer and radiation profiles were obtained. These will be used to make estimates of the depth of sedimentary cover and to help delineate the Arctic sedimentary basin. Excellent correlation was found between scintillation records and the bedrock geology. A large number of sharp magnetic anomalies, believed to be due to basic dikes, were mapped, especially in the vicinity of the piercement domes

Refraction seismic apparatus being used in Costa Rica by the Inter-American Highway office.

on the northernmost islands. About 30,000 line miles were flown in the southern portion of the District of Mackenzie in the Northwest Territories. This adjoins the 1954 survey, and the two areas cover part of the area mapped geologically in 1955 by a helicopter party. Wide bands of steeply dipping lava beds and iron formation were magnetically mapped. These serve as badly needed horizon markers.

Approximately 120 one-mile aeromagnetic map sheets have been compiled during 1955 by the Geophysics Div. In addition, one party has been engaged in field checking the office interpretation of six one-mile aeromagnetic sheets in the Eastern Township of southern Quebec. The party was able to check about 1500 sq miles of the surveyed area. It is estimated that over the past six years Government surveys represent 20 pct of all aeromagnetic surveys done in Canada.

In Ontario a combination magnetic and radiation survey covering approximately 590 sq miles was made in the vicinity of Blind River on the north shores of Lake Huron. In Quebec a survey of 370 sq miles of flat terrace was made along the north shore of the St. Lawrence River near Mingan. It was designed to find out whether iron-sand deposits produce identifiable anomalies, but the data have yet to be processed. Nova Scotia reports that during the past two years 15,000 sq miles of aeromagnetic and scintillation counter surveys have been made. This is two thirds of the total area of the province. Some of the work was done by the Geological Survey at Ottawa and the remainder by private companies. A number of favorable areas have been located, principally for base metals. Follow-up work has been mainly by soil and stream sampling and by ground magnetometer work. Diamond drilling is now in progress.

Surveys for iron ore totaling 5500 sq miles were made over the Lower Yorke and Lower Eyre Peninsula in South Australia. In the Northern Territory of Australia, 3200 sq miles were surveyed in the Port Keats area and 640 sq miles in the Mundogie Hill area. In Jamaica a large area in the eastern part of the island was flown in search of iron deposits by a private investor. Finland reports 16,500 km of survey during 1955; about one sixth of the area of Finland has been surveyed since 1951. In the Philippines a survey of 1316 sq miles over six different islands has disclosed new sources of iron ore. Work by the USGS is reported in the Lake Superior region in iron prospecting and also in the Mojave Desert, Salt Lake Valley, the Colorado Plateau, and Alaska.

Interpretation studies on aeromagnetic data have been provided by Henderson and Zeitz of the USGS. In one paper a magnetic map of the Sudbury area has been used to test the interpretation methods of Vacquier et al. Another paper discusses the geologic interpretation of the Indiana aeromagnetic map. A method of calculating the total intensity anomaly of a three-dimensional body of arbitrary shape has been given by Henderson. A practical and interesting study of the effect of profile spacing on the Marmora iron deposit aeromagnetic map has been presented by Agocs. The deposit, said to contain about 20 million tons of 37½ pct iron ore, is 2400 ft long, a maximum 50 ft wide, and extends more than 500 ft vertically. Ten maps using data for 1, ¾, ½, and ¼-mile spacings and also with ¼-mile displacements show that this feature could have been badly underrated if the line spacing had been too wide.

The **Geological Survey of Canada**, together with **Computing Devices of Canada**, has designed and is assembling a semi-automatic compiling machine for handling airborne magnetometer and scintillation counter data. Magnetometer chart, strip film, and base map are handled on rollers driven by servo motors in such a way that the ratio of their speeds can be preset at values proportioned to the scales. Corresponding points on chart, film, and map can be kept aligned opposite an index line on the viewing table. A photoelectric device automatically follows the magnetometer curve, and the location of 10-gamma intervals along the flight line are automatically stamped on the map. Base maps are prepared in a standard width and assembled in long strips for handling in the machine. Drifting datum lines and flight lines not paralleling the edge of the paper are taken care of by separate servo motors.

Ground Magnetic Prospecting

The promise of new and more convenient ground magnetic surveying instruments was made during 1955 by developments of Varian, Sharpe, and Mooney. **Varian Associates** have adapted the nuclear-precession-type instrument for man-portable use. By relaxing the 1-gamma accuracy requirement in favor of portability, it has been possible to utilize a vibrating-reed-type frequency meter in place of the more bulky binary counters. A field test has shown that a total intensity reading can be made by an inexperienced operator in less than 1 min with an accuracy of about 6 gammas. No orientation or leveling is required. Later developments may include self-recording.

The **Sharpe Instrument Co.** has developed a new self-leveling null-type portable magnetometer, measuring vertical intensity rather than total intensity. The instrument is carried by means of shoulder straps, and a reading can be made in about 1 min. A large gamma range is available.

A moderately priced magnetic susceptibility bridge, based on prototypes built by Mooney at the **University of Minnesota**, has recently been put on the market by **Geophysical Specialties Co.** of Minneapolis. Interpretations of magnetic data depend on some quantitative understanding of rock properties. Susceptibility measurements, even though they may be complicated by sampling, grinding, and handling, are, no doubt, the best means of obtaining this understanding. The complications from anomalous remanent polarization phenomena do not obviate the need for susceptibility measurements. This new instrument should make it possible for all magnetic prospecting people to collect conveniently susceptibility data on rocks.

A program of collecting specimens for measuring magnitude and direction of remanent magnetism has been initiated as a joint project of the **Canadian Geological Survey** and the **Dominion Observatory**. Both astatic and induction-type susceptibility meters are being constructed. The astatic meter will be used for absolute determinations in order to obtain standard samples for calibrating the inductive-type meter, which is both more sensitive and more convenient to use. However, the inductive-type meter is sometimes inaccurate for material which is partially conductive—a shortcoming which is not characteristic of the astatic meter. The project, designed to collect data for paleomagnetic, continental drift and polar wandering studies, will undoubtedly have many prospecting byproducts.

Much of the ground magnetometer work reported for 1955 was in search of iron ore. In the Lake Superior iron region **Oliver Iron Mining Div., W. S. Moore Co.,** and **Jones & Laughlin Steel Corp.** report surveys. According to **W. S. Moore Co.,** the objective on the Mesabi Range is to look for areas of low magnetic intensity within the iron formation which indicate structure where oxidation and leaching have taken place. The magnetics indicate the logical place to locate a drillhole, and frequently only one hole is required to eliminate an entire property.

Columbia-Geneva Steel reports use of ground magnetics in the West to check isolated iron ore prospects and to follow up aeromagnetic surveys. At Nowa-Nowa, Victoria, Australia, a ground survey of a former air discovery disclosed an area which appears to contain considerable iron ore of good quality. A similar follow-up survey is reported from South Australia. And in both Spain and Turkey iron orebodies have been located by magnetic surveys.

Other types of magnetic surveys, principally for base metals, are reported by **St. Joseph Lead Co., Bear Creek, Newmont Mining Co.,** and **Dominion Gulf.** A nickeliferous dunite prospect was surveyed in Central Province, Tanganyika, and a limestone problem was successfully solved by magnetics in Rhodesia.

Seismic Prospecting

Probably the most significant developments in geophysical instrumentation this past year have been those of new seismic data handling equipment made by the petroleum industry. Recording on magnetic tape allows the geophysicist to store the data conveniently and to play them back for analysis under widely varying filtering and mixing arrangements in order to emphasize and make recognizable the most interesting events. Companion developments are the electronic computing and correlation machines. Perhaps some application of these new developments will be made to the complex structural problems so common in mining exploration. Velocity logging devices, originally designed to obtain velocity information for interpreting surface data, have now been developed to provide velocity well logs. These logs have been very satisfactory for correlating formations from hole to hole. At present no mining applications have been reported.

Varian Associates adapted its nuclear-precession-type magnetic design to a light one-man instrument.

In contrast to the former two items, high frequency seismic reflection techniques were developed for the mining industry (MINING ENGINEERING, March 1955, p. 251), and are now finding important applications in petroleum exploration. The equipment has been used for uranium prospecting and structural problems involving buried river channels and dikes. In iron ore mining, for example, the method could be used to determine depth of overburden. Practical depth ranges of investigation are from less than 100 ft to 5000 ft, frequency range is from 30 to 500 cps, and the resolving power is very high.

Refraction seismic equipment has also been much improved. A 12-channel amplifier weighs only 35 lb, and the new 2-cycle seismometers weigh about 17 lb each. Greater sensitivity permits the use of smaller powder charges. Clear definition of first breaks greatly increases the accuracy and resolution of the method as used today.

Since the inception of the seismic method of prospecting, consideration has been given the generation of elastic waves by dropping weights rather than detonating explosives. A rejuvenation in the use of this type of wave generation has recently been taking place. One system known as the *thumper*, or *geograph*, generates seismic waves by dropping a 3-ton weight. Seven crews commercially using such techniques in petroleum work were reported during 1955.

St. Joseph Lead and **Bear Creek** both report some use of the reflection seismic method during the year. **Jones & Laughlin** used the method in its exploration for lean iron deposits in the Lake Superior district of the U.S. and Canada. **Seismos** in Germany reports surveys in Western Germany, Belgium, and central Africa on coal, iron, and copper problems. The Dept. of Mines of South Australia conducted a seismic refraction survey to locate the extension of iron ore bearing formations near Iron Knob, South Australia. The results were considered of doubtful value, owing to the complexity of the structures and the lack of definition of boundary surfaces.

The **Illinois State Geological Survey** gives an example of a successful seismic refraction survey in its *Report of Investigation No. 176* in which the contact of the Wisconsin and Illinoian drift sheets was accurately mapped.

Field and instrument developments of the reflection method were continued by **Bear Creek** and the **USGS.** Seismos in Germany reports developing new reflection equipment, especially for mining work. At **Penn State** Prof. Ben Howell is making a quantitative study of the energy resulting from the impact of a falling weight in comparison with that generated by small explosions. Although his work is in progress, he states that 700 ft-lb of impact energy create disturbances of about 1/10 to 1/100 of that from ½ lb of dynamite buried at 10 ft.

Electrical Prospecting

Electromagnetic Surveys: Ground electromagnetic surveying has received a very great stimulus from airborne electromagnetic work, and the reports here undoubtedly represent only a fraction of the work done during 1955.

Cleveland-Cliffs Iron Co. with **McPhar Geophysical Co.** successfully adapted an induced electromagnetic method as an aid in mapping iron formation in the ranges of Michigan and Minnesota. **New Jersey Zinc Co.** reports that electromagnetic methods

are its principal exploration tool for exploring for sulfide orebodies in eastern Canada and the U.S. **Dominion Gulf** has been identifying and tracing conductive zones in base metal exploration. **Bear Creek Mining Co.** and **Newmont Exploration Co.** report use of the method. It appears that some interpretation difficulty exists in discriminating between sulfide and graphite responses. Important surveys have been made by the **Commonwealth of Australia** in the Montana silver-lead field, the Mt. Lyell copper field, and the South Mount Cameron tin field—all in Tasmania. At the Waterhouse Ranges, Northern Territory, low grade copper mineralization was identified. In Africa ground electromagnetic methods have been used in tin and copper prospecting in the Transvaal. Two electromagnetic field crews have been employed in Finland using the Swedish loop frame method.

An electromagnetic logger built by the **Houston Technical Laboratories** has been recently displayed and advertised. The device is intended to log mining exploration drillholes to determine proximity to mineralized conductors even though the drill did not intersect mineralized ground.

Resistivity: Resistivity-type exploration for base metals in 1955 is reported by **St. Joseph Lead Co.** and **Newmont Explorations Ltd.** The **Price Exploration Co.** and the **USGS** have used the method in uranium studies in Colorado and New Mexico. However, the most extensive application has been in ground water prospecting.

An important contribution to resistivity interpretation methods is soon to be published by Mooney and Wetzel of the **University of Minnesota.** This book will provide tables of data on potentials about a point electrode and apparent resistivity curves for a four-layered earth. Included are curves for approximately 2700 cases. The **Compagnie-Générale de Géophysique**, Paris, has also announced that 500 curves on three-layer cases are ready for publication. Similar works are expected from the **Royal Dutch Shell Co.** and the **Geological Survey of India.**

Other Electrical Methods: In 1955 **Dominion Gulf** surveyed three base metal prospects and did some reconnaissance work with **self-potential equipment.** In Quebec 22 surveys were reported. A few surveys on copper-bearing deposits were made in Turkey. Results of prospecting for nickel and zinc in the Union of South Africa were disappointing, but success is reported from the Barberton goldfields. In Jamaica use of the self-potential methods has been proposed in connection with the study of lignite deposits. Seismos in Germany reports application of the method.

Work with **induced polarization** in the U.S. has been reported by **Bear Creek** and the **USGS** and in Italy by **Belluigi.** Circular line electrodes were used by **Bacon** in southwest Wisconsin to determine the trend of narrow sulfide deposits.

Gravity Prospecting

Gravity surveying continues to be a minor method in mining exploration, but current developments increase its usefulness. William Allen of **Phelps Dodge** has developed new procedures underground in the Douglas, Ariz., area. Data collected in mine crosscuts are corrected for terrain and regional effects projected from the surface. A vertical section gravity contour map is then constructed which is reported to be very helpful in ore studies. Similar density section maps are being tried. Much of the data handling is by IBM machines. Other new computing machines, such as the Ferut electronic computer at the University of Toronto, are being effectively used in analyzing gravity data.

Current developments are increasing the usefulness of gravity surveying in underground exploration.

W. S. Moore Co., Oliver Iron Mining Div., and the **USGS** have all reported using gravity surveys in the Lake Superior region during 1955 to explore for iron. On the Vermillion Range the method is used in conjunction with magnetic measurements to locate zones of rich iron formation within zones of low grade iron formation. Last year in this Review, the regional survey of the Upper Michigan Peninsula was reported completed. Analysis of this data now indicates that there is excellent correlation between gravity maxima and the thick Huronian sedimentary basins which contain iron formations. Local anomalies may have significance as a guide in iron ore prospecting, according to Professor Bacon of the Michigan School of Mines and Technology.

H. O. Seigal reported on a gravity survey in search of deeply buried base metal sulfide deposits near Bathurst, N. B. Useful structural data were obtained, and high density areas that would include any large deposits were localized. Chromite exploration in Cuba has been continued by the **USGS.** Anomalies as small as a few tenths of a gravity unit have been successfully mapped. To date five chromite orebodies have been discovered by drilling on gravity anomalies. Both **St. Joseph Lead Co.** and the **Bear Creek Co.** report the use of gravity methods in 1955, probably in structural studies for base metals. (See p. 100.) Woollard of Wisconsin continued his worldwide gravity survey sponsored by the Air Force and the Navy.

In Dutumi, Eastern Province of Tanganyika, a gravity survey was made to investigate the thickness and structure of the Karroo formation in connection with coal prospecting. The results were inconclusive, and no confirmatory drilling was done. Another survey here used gravity methods in conjunction with magnetic and spontaneous polarization methods in gold prospecting.

At the University of Toronto, Professor J. T. Wilson has had his students making a regional survey of the southern Canadian Shield. This year, the work was continued on the islands of Georgian Bay, Lake Huron. Theses are now available by Oldham

and Sutherland in which they interpret gravity measurements made along the Alaskan Highway and an area of pre-Cambrian rocks between Lake Huron and the Ottawa River. A regional survey was made by W. A. Black of the California Co. from the northeast corner of Kansas to the northwest corner of Wisconsin.

Surveys by the USGS continued in the Mojave Desert and Owens River Valley in California, in the Salt Lake and Utah Valleys, Utah, and Crescent Valley, Nevada. The data are reported to be extremely valuable in interpreting the Cenozoic history and structure in the Great Basin. The South Australian Dept. of Mines reports regional surveys over sedimentary basin areas in which levels were obtained barometrically with microbarographs at the base stations and significant information was obtained on bedrock structure. In Turkey the gravity survey in the central part of Anatolia started in 1953 has been continued.

Geochemical Prospecting

The trend in geochemical surveys is shown by an analysis of the papers given at the **Geological Society of America** meeting in New Orleans in November 1955. Of a total of 267 papers abstracted, 26 pct were devoted to some phase of geochemistry.

Canada: The geochemical survey activity of the Geological Survey of Canada is reported by R. W. Boyle. During the 1955 field season the dithizone method was used to investigate the heavy metal content of stream and spring water of the Galena Hill-Mount Haldam area and dispersion patterns in the soils of the Keno Hill-Galena Hill area (Yukon Territory). In the former, a southwestern extension of the known mineralized zone was effectively outlined which confirms the 1954 work, and several significant anomalies were found in previously unprospected areas. Permafrost conditions do not appear to restrict the method except locally.

The soils were investigated to see whether they could be used for prospecting for lead-zinc-silver deposits in the permafrost region. Analysis of partly residual soil across known mineralized vein faults shows that the lead content is several times the background. Where ore shoots containing lead, zinc, and silver are present in the vein faults, the lead content of the soil in their vicinity is from 10 to 100 times greater than background. Analyses of near-surface glacial tills, gravels, and peats across known vein faults or ore shoots showed no appreciable rise in heavy metal content. Samples of glacial material taken close to bedrock, however, gave good heavy metal anomalies. Permafrost conditions do not appear to influence the dispersion patterns but make sampling more difficult.

Research using spectrograph, mass spectrograph, and X-ray is being conducted to determine primary and secondary dispersion patterns of several elements in the vicinity of metal deposits.

In Quebec in 1953, J. E. Riddell made an experimental survey in Lemieux Township, Gaspé, North County, to establish whether the analyses of soil and water samples by the dithizone method would be useful for prospecting in a hilly, unglaciated region. Quebec Dept. of Mines *Preliminary Report No. 302* reports the results, which were favorable. In the summer of 1955 S. V. Ermengen made similar measurements in the Chibougamau District where there are known deposits of copper, gold, and zinc. During the 1954 field season, F. W. Cornwall continued a series of studies on wall rock alteration associated with sulfide mineralization and has now completed his report on the Barvue, Golden Manitou, and New Calumet deposits. Samples were obtained mainly from diamond drill cores so as to obtain sections across the ore zone and for varying distances of the footwall and hanging wall sides.

During the year the **Dominion Gulf Co.** equipped a geochemical laboratory for carrying out soil analysis for copper, lead, and zinc. Field men were furnished kits which could be used for preliminary guidance. Surveys were made principally in New Brunswick and the prospective area for base metals in northern Ontario.

Virtually every large exploration company in the Bathurst District of New Brunswick is reported to have integrated both geochemical and geophysical work with their routine exploration programs. These include principally soil and water analysis and both airborne and ground electromagnetic methods. A large-scale geochemical reconnaissance survey for copper, lead, and zinc deposits has been under way for three seasons by one group in New Brunswick and adjoining areas of Quebec. The work is based on systematic analysis of fresh stream silt for traces of metal soluble in cold citrate solution.

In Nova Scotia several private companies have been conducting magnetic and soil and stream geochemical surveys to check anomalies first mapped by extensive airborne magnetic and scintillation counter surveys. It is reported that diamond drilling is now in progress to test out the mineralized zones so discovered.

United States of America: The **Geochemical Exploration Section** of the **USGS** continues active in both service and research. The section trained about 15 geologists and 25 chemists in the laboratory at the Denver Federal Center. Publications on research include those on methods for rapid determination of germanium in coal, soil, and rock; for determining trace amounts of copper and niobium in soil and rocks; and for determining citrate-soluble zinc in soils. A new ceramic buckboard and muller to avoid contamination and a multiple fusion rack have recently been developed.

Adler and Axelrod have reported on a new four-channel, X-ray spectrograph built by the **USGS Geochemistry and Petrology Branch.** Rapid techniques have been developed for determining uranium niobium, tantalum, rubidium, cesium, and selenium. A quantitative analysis for such elements as thorium can be made in an hour or less. Soil samples for geochemical prospecting with a lower limit for zinc of 50 ppm and for lead of 75 to 100 ppm can be analyzed in 2 to 3 min per sample. Canny, Meyers, and Ward have issued a preliminary report on a new truck-mounted spectrographic laboratory, which has been constructed and field tested by the USGS and has proved comparable to similar stationary laboratory equipment. In June 1955 the laboratory was driven 525 miles to a field project near Eureka, Utah. All equipment remained in good working order, and the laboratory was ready for operation less than 2 hr after arrival.

A two-year investigation of geochemical prospecting techniques in Montana has been conducted by Forbes S. Robertson of the **Montana Bureau of Mines and Geology,** and a bulletin reporting on this work is expected to be off the press early in 1956.

Spectrographic determination of trace elements in lake waters was applied as a reconnaissance pros-

pecting method to a remote area in northern Maine containing approximately 20,000 sq miles; 689 water samples from 467 lakes were analyzed. Data was collected on Cu, Pb, Zn, Ag, Sn, Ni, Cr, Mn, Mo, Va, and Zr. The data, when correlated with known geologic features, provided the bases for recommending three limited zones, each of less than 40 sq miles for more specific studies for the occurrence of lead, silver, zinc, and copper. This work was by M. D. Kleinkopf of **Standard Oil Co. of California.**

New Jersey Zinc, St. Joseph Lead, and **Newmont Exploration** report geochemical surveys principally in the eastern U.S. and Canada. **Bear Creek Co.** indicates that research is being conducted to adopt the geochemical techniques to the particular environments which they encounter. The very interesting case history report on the Chollet Project by **American Smelting & Refining Co.** notes that detailed hot-method soil sampling was successfully indicated anomalously high zinc in a transported glacial soil.

Other Foreign Reports: In the Commonwealth of Australia, the **Bureau of Mineral Resources, Geology, and Geophysics,** had one geochemical party that operated in an area southeast of Darwin, Northern Territory, with one Landrover, two trucks, and a mobile chemical laboratory. One six-week survey covering 4 sq miles was made to assist a company locate possible extensions of a lead prospect discovered in 1954. A cold acid colorimetric dithizone technique was used to determine lead in soil samples, and two large and intense lead anomalies were discovered. The company will probably drill at least one of these anomalies to evaluate the work.

Maunu Puranan of the **Geological Survey of Finland** reports that two persons were engaged in geochemical surveys that resulted in successful aids in ore prospecting. Two methods, although still in the development stage, showed promise: 1) chemical analyses from the fine-grained material of moraine and 2) prospecting for bog-covered ores by means of peat investigations.

Research studies on chromite and gold-arsenic-antimony associations are being made in Rhodesia by a research graduate of the Royal School of Mines. In Northern Nigeria, the Geological Survey is making spectrographic investigations of trace elements in the "Younger Granites" (pre-Cambrian) with which are associated tin and niobium mineralization.

In London, the **Royal School of Mines** Dept. of Geology has recently completed a new laboratory for research in geochemical methods of exploration, and it has already become the coordinating center for a very large amount of both commercial and government work throughout the British Commonwealth.

Uranium Prospecting

The **USGS,** in cooperation with **AEC,** has used gravity, aeromagnetic, and geothermal methods to study regional geologic features to localize uranium ore on the Colorado Plateau. Other uranium geology problems have been attacked by shallow reflection seismograph, induced polarization, and electric and gamma-ray logs. Considerable success has been achieved in mapping buried Shinarump channels using seismic refraction, resistivity, and electromagnetic methods. The Geochemical Exploration Section is currently completing work on methods for the determination of uranium in soils, rocks, and water.

The **Bureau of Mineral Resources, Geology, and Geophysics** of the Commonwealth of Australia has also applied a number of methods to uranium exploration. At the Carcoar cobalt-uranium fields, N.S.W., electromagnetic (Turam), magnetic, and self-potential methods were applied on an area of old cobalt workings. The Turam method gave well-defined indications that were attributed to mineralized shears. No satisfactory results were obtained from the self-potential method. The magnetic anomalies indicated the boundary of the diorite and slates, and the uranium mineralization seems to be confined to the vicinity of this boundary. A regional gravity survey consisting of 550 miles of traverse was made at 5-mile intervals of the Northern Territory to assist in studying uranium-bearing formations.

Five months were spent investigating the use of geochemical methods in uranium prospecting. Previous tests in 1954 indicated that soil tests gave more intense anomalies than vegetation tests. Fluorimetric methods were used for the uranium determinations. All the known deposits were represented by anomalous amounts of uranium in the soils in their vicinities, and several small anomalies were discovered in areas not previously known to be mineralized. A detailed survey over a known deposit indicated that the 100 ppm uranium anomaly coincided with the eight times background anomaly obtained with Geiger counters, which was considered to be a significant radiometric anomaly. Hydrochemical prospecting for uranium, using an ion-exchange resin extraction of the water samples followed by fluorimetric tests, gave positive indications in many springs and creeks.

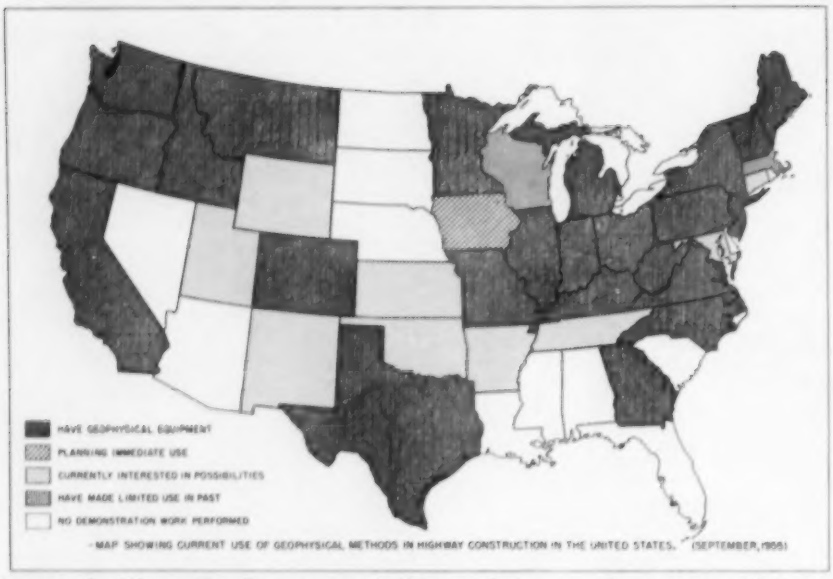
In both Australia and the Union of South Africa, old drillholes have been resurveyed with resistivity and radioactivity logging methods in the search for uranium.

In the western U. S., **Price Exploration Co.** used resistivity and Radore methods in its uranium search. The Radore method, originated by William J. Barrett, was used in Utah, Wyoming, and Washington. It is reported that there is a definite relationship between the attenuation of propagated radio waves beneath the surface and uranium mineralization. One orebody was mapped which had previously been drilled out, and the correlation is reported to be excellent. Other unknown bodies have been mapped and subsequently checked by drilling. The Radore work requires a party of three, and it is possible to cover several miles of profile a day.

Engineering Geophysics

It appears that the use of geophysics in engineering problems is very much on the increase. R. W. Moore of the **U. S. Bureau of Public Roads** has provided a most interesting review of this work.

As of Dec. 31, 1955, geophysical methods have been employed in more than 38 of the 48 states in connection with highway construction and other engineering work. The Physical Research Branch of the Bureau of Public Roads has conducted subsurface surveys or performed extended demonstration tests in 31 of these states. As a result there are now 25 state highway departments which either have geophysical equipment or have a cooperative arrangement with some other agency within the state, such as the Geological Survey or a university, making available facilities for geophysical exploration in connection with highway problems. In addition, ten others states have shown an increasing interest in the possible use of geophysics in future subsur-


HAVE GEOPHYSICAL EQUIPMENT
PLANNING IMMEDIATE USE
CURRENTLY INTERESTED IN POSSIBILITIES
HAVE MADE LIMITED USE IN PAST
NO DEMONSTRATION WORK PERFORMED

MAP SHOWING CURRENT USE OF GEOPHYSICAL METHODS IN HIGHWAY CONSTRUCTION IN THE UNITED STATES. (SEPTEMBER, 1955)

By the end of 1955 more than three fourths of the states were using or were interested in using geophysical methods in connection with highway and other construction programs. Twenty-five states now have their own equipment. Earth resistivity is the most widely used technique.

face explorations. For the most part, this geophysical activity has been limited to use of the earth-resistivity test procedure, although at least five states are also making use of the refraction seismic test. The accompanying map shows the current use of geophysical methods in highway construction in the U. S. as of September 1955.

During the past 12 months, the Bureau of Public Roads has engaged in geophysical studies and demonstration tests in six states and four Central American countries: Costa Rica (see photograph), Guatemala, Nicaragua, and Panama. The work in Central America involved subsurface exploration on uncompleted sections of the Inter-American Highway in Panama, Costa Rica, and Nicaragua, on the Rama Road in Nicaragua and the Pacific Highway in Guatemala. During the three-month period spent in Central America, 40 engineers were given training in the use of the geophysical tests. In addition, training and demonstrations were given to 14 engineers visiting the United States from ten foreign countries during the year.

There has been increased activity in other countries as well. East Pakistan has acquired earth-resistivity apparatus during the past few months for use in a nation-wide survey for the construction materials that are scarce in that country. Turkey, having become actively engaged in the use of geophysics in highway work in the fall of 1953, recently obtained four additional earth-resistivity units to expand geophysical exploration program.

J. F. Enslin of the Union of South Africa reports the use of resistivity methods on possible sites for bridges and dams, especially where the bedrock is igneous. The data are used to prepare contour maps showing depth of alluvium or weathered rock. Where no resistivity contrast exists, the seismic refraction technique using a sledge hammer as a seismic energy source has been employed to determine contacts down to 100 ft. Magnetic, resistivity, electromagnetic, and gravity methods have been used in dolomite areas south of Pretoria to delineate sink holes, which cause damage to buildings, reservoirs, airport runways, and roads. In the U.S. a similar problem solved by resistivity methods was used by St. Louis University to locate old mine workings.

A dam foundation investigation in Kidunda, Eastern Province, Tanganyika, is reported. Resistivity methods, used to interpolate the bedrock profile between drillholes, located a number of unsuspected washouts and bedrock ridges. A mining engineering investigation is in progress at the **Michigan College of Mines and Technology** in which microseismic mine noises are being located by seismic triangulation. The **University of Munich** in Germany has made a number of engineering-type seismic studies in tunnels and on dam sites.

Groundwater Geophysics

According to A. N. Sayre of the **Ground Water Branch** of the **USGS**, the application of geophysics to ground water exploration has increased substantially in recent years, principally for two reasons: 1) the availability of portable well-logging units and 2) the greater recognition that logging methods provide valuable information on the thickness and areal extent of water-bearing formations and the chemical quality of the water. The principal geophysical methods used by the Ground Water Branch are electric and radioactivity logging, and there has been a decrease in the use of surface (Gish-Rooney) methods. Seismic methods are used for determining depth to bedrock, and geochemical measurements are used to determine the character of the water.

The **Illinois State Geological Survey** reports highly satisfactory results from its resistivity program for locating water-bearing sands and gravels. New approaches to the problem of detecting water-yielding materials beneath varying thicknesses of silt so common in the large river flats of Illinois are being studied. Spontaneous polarization, a refined resistivity technique, or a combination of both is being considered. The first resistivity surveys for water in Kansas were made by D. F. Merriam of the **State Geological Survey.** Alluvium-bedrock contacts were mapped in the Kansas River Valley, and, within limits, the depths to the water table and to bedrock were determined.

Ground water surveys in Africa have been extensive and quite successful. Enslin reports that 10,000 boreholes are drilled annually in the Union of South Africa. In at least 75 pct of the areas investigated

for such sites, the evidence from geological exploration must be supplemented by geophysical work. Because of the various conditions that are encountered in such work, he predicts that many new techniques will have to be developed and that there will be a great expansion in ground water geophysical activity. He notes that water prospecting differs from mineral prospecting in that the economics involved require that the work be done using field techniques requiring not more than two or three days and at a cost not to exceed about $150. Magnetic methods are used where the water is controlled by dikes, but resistivity methods are most effective in basins of decomposition of igneous rocks, and electromagnetic methods are used for fault planes and fracture zones. Extensive ground water surveys using logging and surface resistivity techniques primarily are reported from Nigeria, Rhodesia, and Tanganyika. The Hydraulic Branch of the **Public Works Department of Kenya** reports that 80 pct of the boreholes drilled on geophysical evidence have been successful.

In Spain three areas were surveyed for water with resistivity methods in which excellent results were obtained. In Jamaica two ground water surveys were made, one using the Wenner method for locating gravel aquifers, and the other using Coopers electrode arrangement to determine depth to a limestone formation. Resistivity ground water surveys are also reported from the Leeward Islands.

Nobel Muñoz has conducted ground water surveys in the western area of Buenos Aires, in Santa Fe Province, and in Patagonia. In Santa Fe Province, where official statistics indicate less than 1 pct success for wells located without technical assistance, he reports that holes located on the basis of his work are practically 100 pct fresh water producers.

Education

Educational problems in geophysics are similar to those in other branches of mineral education and include: accreditation, general education pro and con, how to design a four-year professional undergraduate course, and how to interest good students early in their college career.

The accreditation problem stems, at least in part, from the varied definitions of the term *engineer*. The Engineering Council for Professional Development (ECPD), of which AIME is a member, does the accrediting job. The geophysicists can probably best be served by using the AIME Mineral Industry Education Div. as a forum.

The general education trend is part of the accreditation problem, since it becomes an almost insurmountable task to satisfy the ECPD requirements for general engineering, university requirements for general education, the geophysicists' requirements for general basic science, industry's requirements for general technical training, and the students' inclination. In addition to these pressures, it frequently occurs that a student becomes interested in geophysics during the sophomore year; if so, he probably will be plagued for the remainder of his college career by prerequisite course problems. To attract students early in their college career, Professor Howell of Penn State suggests that the high schools should be provided more information and scholarships be offered to freshmen.

In 1955 there appears to have been a trend toward more geochemical training and research. **Pennsylvania State University** reports 14 graduate students in geochemistry, as compared with 11 in all geophysical studies. **The University of Wisconsin** reports a similar situation. Others indicate that new geochemical laboratories have been installed or that there are plans to provide them. Notable are the facilities at the **Lamont Geological Observatories** of **Columbia University,** at the **Massachusetts Institute of Technology,** and at the **Royal School of Mines** in London.

New developments in geophysics curricula and facilities have been supplied by a number of universities. J. L. Soske of **Stanford University** set up a new four-year curriculum that emphasizes general education during the first two years but provides for prerequisite courses. The last two years emphasize basic science fundamentals and provide introductory geophysics courses only; specialization is reserved for graduate studies. Prof. G. P. Woollard of **Wisconsin** has devised a similar plan in which undergraduate geophysics courses are limited to four. J. A. Norden of **Oklahoma University** has a new four-year curriculum that emphasizes basic and advanced courses in mathematics, geology, physics, and geophysical interpretations. A new curriculum for 1956 has been announced by Lloyal Bacon of **Michigan College of Mines and Technology,** for which new laboratories are being provided by the **Bureau of Mineral Research.** R. J. Uffen of the **University of Western Ontario** at London says that geophysics students there obtain degrees in either the geology or physics departments. One formal undergraduate course and two graduate courses are given, and equipment is available for practical laboratory and field exercises. At the **University of Minnesota,** Harold Mooney has instigated a five-year undergraduate course leading to the degree of Bachelor of Geophysics. J. T. Wilson of the **University of Toronto** reports that the faculty in geophysics has been increased to five and now includes R. M. Farquhar and R. Doell, who recently came from MacMaster University and the University of California, respectively. The **University of Utah** has increased its geophysics staff with the addition of J. W. Berg, who moved from Tulsa. Radioactivity courses have been added to the curriculum, and new laboratories are under construction.

McGill University in Montreal is now offering a new Master of Science (applied) degree titled "Master of Mineral Exploration." Two options are provided, one for mining engineers and one for geologists. Two years are required to complete the course provided the student has fulfilled undergraduate requirements. A new geophysical laboratory is being fitted out, and an impressive list of geophysical exercises are being scheduled.

Kasim Ergin of the **University of Istanbul** in Turkey reports that the **Geophysical Institute** has conferred degrees in geophysics for the first time and that fourth-year students of the mining engineering dept. of the **Technical University** are now taking a course in geophysics.

Acknowledgment

Some 250 questionnaires were mailed to all parts of the world, and about 110 replies were received. Support for the work was provided by Columbia-Geneva Steel Div. of the U. S. Steel Corp. Miss Francine Appleman performed the extensive stenographic work, and Miss Mary Blakeslee helped in preparation of the manuscript. Sincere appreciation is extended to all who so generously gave their time and thought to the project.

Gaspé Copper Mines Ltd.

Beneficiation in 1955

by Will Mitchell, Jr.

Renewed fundamental research in comminution

Nonmagnetic taconite research intensified

General revival of interest in leaching

THE classical definition of a beneficiation engineer as one who *treats an ore in order to separate and discard worthless fractions by essentially physical means* is obsolete. Technology in the profession has advanced so rapidly during the last two or three years that educators have not been able to coin definitions to keep up with the pace. In the past some people have hesitated to include leaching or even agglomeration as minerals beneficiation, because of the major chemical changes involved. This view has fallen by the wayside, especially because a majority in the profession have become actively involved in extraction and pyro processes that go far beyond the original definition of mineral dressing.

To say that there is a great revival of interest in leaching is putting it mildly, for the uranium business, like the gold business, now depends almost entirely on leaching. This revival of leaching, long overdue in mineral engineering, has been stimulated this year, especially as a result of the relaxation of security restrictions surrounding the recovery of uranium from its ores. It has brought new unit operations to minerals beneficiation, namely ion exchange and solvent extraction. These operations have appeared as resin-in-pulp, solvent-in-pulp, and liquid-liquid systems. In many cases these leaching and separation procedures, now reaching the production stage, have been engineered by minerals beneficiators. The trend toward leaching has also had impact on the technology of beneficiating other nonferrous minerals, especially copper, manganese, columbium, tantalum, nickel, cobalt, titanium, and the rare earths.

There is growing interest in utilizing minerals beneficiation processes that offer great flexibility in choice and arrangement of unit operations. A number of installations have been realized in which flotation has been combined with leaching or with roasting, leaching with magnetic separation, or gravity concentration with roasting.

Great attention is being given the possibility of using mineral dressing techniques to clean up slags and other metallurgical byproducts. There is also much speculation about using mineral dressing operations either following or intermediate to metallurgical processes. Flotation of copper-nickel matte as practiced at **International Nickel Co.** is a prize example of what can be done by beneficiating metallurgical products. Other separations are being devised that will use preliminary reduction before concentration.

Technical developments, however, are being hampered by the scarcity of young engineers enter-

WILL MITCHELL, JR., 1955 MBD Chairman, is with the Research Div. of Allis-Chalmers Mfg. Co.

ing the mineral beneficiation field. Also the curricula in many colleges have not incorporated the new unit operations in mineral dressing courses. This situation is serious, and at the moment there is little prospect of early improvement. However, Massachusetts Institute of Technology is pioneering a sophomore course in which classical mineral dressing and pyro and hydrometallurgy will share honors.

Not only is there a shortage of mineral engineering students; there is also a shortage of capable instructors. It would seem that inspired teaching is becoming a lost art. During the year several authorities have voiced the opinion that pragmatism has invaded many colleges through the guise of sponsored, but specific industrial research. A few hours of teaching have become the penalty a researcher must pay if he is to harvest the glory and financial remuneration from his sponsored research. However, a ray of hope shows on the horizon: groups of enlightened industrialists have contributed funds for basic research—with no strings attached. The area of research and the administration is being left to the discretion of the university.

The engineering school's lack of interest in the student during the past 10 or 15 years is reflected by the student's lack of interest in the engineering schools today. Industrial sponsors have been wooed over the past 15 years until now some mineral dressing departments have more research sponsors than they have students.

In the 1954 MINING ENGINEERING Annual Review, Norman Weiss and Stanley D. Michaelson wrote prophetically, "It can already be conservatively predicted—from the technological point of view—that 1955 and 1956 will be tremendous years." This prediction has been justified. The technical program of MBD at the 1955 Annual Meeting of AIME included more papers on research and technology than ever before. Since many of these papers will be published, they will not be reviewed here.

This year has witnessed a notable trend toward thorough research in process development before plant construction. This is a natural consequence of the size of the units being put into operation. The country's process laboratory facilities have been taxed to the limit and new facilities have been added. Michigan College of Mining and Technology has announced the opening of a new mineral dressing laboratory equipped for the study of local beneficiation problems, with special emphasis on copper and iron.

Both producers and manufacturers are stressing pilot work prior to design of producing units in both the sintering and pellet firing fields. Among the producers, **U. S. Steel Corp.** has completed a sintering unit in a research center at Monroeville, Pa. The installation is reported capable of continuous pilot operation and incorporates bins and feeders with the usual line of intermediate equipment found in operating plants. The sintering machine is the smallest Dwight-Lloyd machine manufactured. **Jones & Laughlin Steel Corp.** has reported a continuous pilot machine to improve quality control on its large unit. **Koppers Co.** has opened its sintering laboratory at Swissvale, Pa., and **McDowell Co.'s Dwight-Lloyd Div.** has opened a research center in Cleveland. The Cleveland center is said to be the most complete pyro processing laboratory built so far, with an operating range from simple pot grate tests to full-scale pilot production runs on both up and down draft sintering machines. In Canada a 150 tpd pilot plant was placed in service at the lead-zinc property of the **Brunswick Mining & Smelting Co.**

During 1955 the beneficiators met in Chicago for the AIME Annual Meeting, where 44 technical papers were presented. During the autumn, regional meetings called the technical men to Salt Lake City; Rapid City, S. D.; and Spokane. Of world-wide interest was the International Ore Dressing Congress held in Goslar, Harz, West Germany, where several Americans contributed. An outstanding paper, *Concentration of Materials other than Natural Ores*, was presented by H. Rush Spedden. A contribution to the International Conference on the Peaceful Uses of Atomic Energy held in Geneva, Switzerland, in August was A. M. Gaudin's paper, *Principles and New Developments in Uranium Leaching*.

Crushing and Grinding

Until recently fundamental studies of comminution have been sporadic. Several hypotheses have been argued, usually on the basis of empirical relationships derived from accumulations of field data. Although this empirical approach has been a tool for the engineer to use in proximate selection of a crusher or a mill for a specific operation, it has contributed little or nothing toward establishing basic principles of the brittle fracture of homogeneous solids—to say nothing of heterogeneous materials. During the past year or two there seems to have been a rebirth of fundamental research in comminution. Several university and industrial research organizations are approaching their investigations from the viewpoint of physics and mechanics, and for the first time there is a trend toward pooling ideas and data. R. J. Charles and P. L. de Bruyn of MIT have investigated the stress conditions in a glass rod fixed at one end and struck longitudinally at the other with objects of varying mass and velocity. The work indicates that the impacting mass should be small and the velocity high to get the most useful results. C. L. Sollenberger and R. B. Greenwalt at **Allis-Chalmers Research Laboratories** are investigating the application of energy to glass balls of selected diameters to the point of brittle fracture with the energy applied by slow compression at different rates of loading. Both groups are using ingenious measuring and recording apparatus to quantify their variables.

N. Arbiter and his group at Columbia University are correlating variables of the rod mill and appear to be approaching the problem from the standpoint of fluid mechanics. A dimensionless number such as the Reynolds or the Froude number would be invaluable in the technology of rotating mills.

An investigation of the impact strength of limestone at temperatures up to 900°F has shown that the impact strength of minerals at this temperature is about half the value at room temperature. An operator in New England has been taking advantage of this phenomenon by heating quartz to a red heat in a rotary furnace and discharging it to a hammermill.

On the immediate scene, J. F. Myers is urging that emphasis be placed on *metallurgical grinding* rather than on *mesh grinding*. By grinding an ore only to the liberation of the desired mineral and with minimum fracture of the valuable mineral, metallurgical efficiency can often be gained in the concentration process. Myers plots the size distribution of the

The Reserve Mining Co.'s E. W. Davis Works near Beaver Bay, Minn. Concentrator is in foreground; power plant at left distance; and pelletizing plant is under construction at right.

gangue alongside the size distribution of the mineral on a log-log curve. He is studying means of controlling the crossover point.

One pilot mill reports that the Aerofall mill is doing an excellent job of metallurgical grinding. The −8 mesh product from the mill is sent to spirals, and with the present setup the −100 mesh has been reduced to 15 pct with subsequent improved metallurgy in the spirals. A rod mill closed-circuited with screens in a parallel circuit produces 25 pct −100 mesh. In cases such as this the improved metallurgy usually more than pays for any higher grinding and classification costs. Reports from other places around the world indicate that the Aerofall mill is justifying its existence.

The 42-in. vibrating ball mill is still undergoing field tests in Illinois. Mechanical difficulties are being worked out and new construction materials are being tried. Recent tests have shown that improved capacities can be obtained in many cases when rods are used as a grinding medium instead of balls. One such mill being tested has been designed to run at or near critical speed to take advantage of lower power demand at resonance. Because the vibrating mill does not rotate and seals offer no problem, it has been applied this year in a hydrometallurgical system where the ore is being ground in contact with the leach liquor. The mill has been externally heated and is operated under pressure.

A. W. Fahrenwald announced important mechanical changes in the gyratory mill and has presented a paper showing the mill to have a capacity four to seven times that of a conventional ball mill of the same volume.

J. K. Moore of **Moore-Lowry Research**, Tucson, Ariz., has invented a grinding machine operating on an entirely new principle of size reduction. The machine accelerates particles to high speed and then discharges them against a curved surface, causing the particles to spin about their own axes. The inventor claims the centrifugal force thus created is sufficient to cause them to explode. Because they spin at velocities proportional to their weight, the larger particles are reduced more quickly and a uniformly sized product is obtained.

Debate still goes on over rod mill-ball mill circuits vs single-stage ball mill grinding. The subject is particularly pertinent in the design of the big copper plants. The rod mill-ball mill circuit adherents have the edge at present because they are able to provide more flexibility in case of orebody changes, and the circuit provides an opportunity for the recovery of soluble copper salts following the primary grind. Also, the combination circuit decreases the load on the final crushing stage.

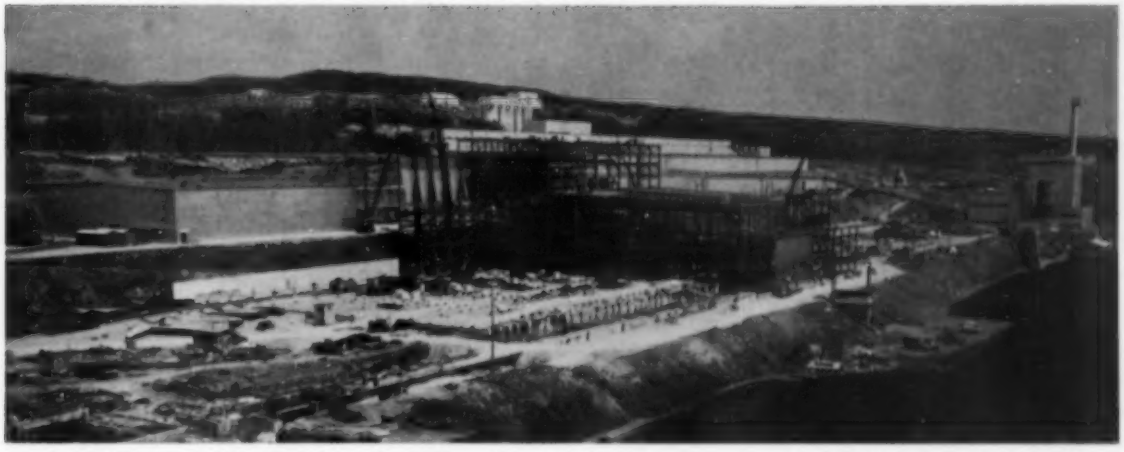
Climax Molybdenum Co. is doing work with spiral-type liners in one of its ball mills. F. J. Windolph reports that production obtained exceeded his fondest hopes, and the energy consumption showed some improvement. Although a great many variables encountered with the use of spiral liners will have to be studied, the Climax mill men have enough confidence in their present design to continue the work on an expanded scale. The spirals move the pulp and balls toward the feed end of the mill which is probably opposite to common practice. Another innovation at Climax has been the setting up of specifications for 13x12-ft low speed, 65 pct critical, overflow-type mill to be driven by a 1000-hp synchronous motor. This will be a radical change from the company's present practice of high-speed mills. Final design of the mill was based on size of the motor rather than on tonnage required.

The first rod mill ever to be installed in a cement plant will grind raw mix wet and prepare feed for a 7x22-ft tube mill. The rod mill is 7x14 ft and will be installed in the Detroit plant of **Peerless Portland Cement Co.**

Last year it was reported that the **General Portland Cement Co.** was purchasing the largest ball mills, 13 ft x 16 ft 3 in., and since that time several of these large mills have been installed in other operations. However, this year six of the world's largest ball mills in regard to horsepower were ordered by **Ideal Cement Co.** These 11x32-ft compeb mills each have 2000-hp motors.

Solids-Fluids Separation

Many years ago the clay industry was rejuvenated with the advent of the high speed centrifuge, but for some time the industrial minerals industry has been held back in its dry process operations by the lack of highly efficient air classifiers. It has been obvious that an air classifier with an efficiency comparable to that of existing wet classifiers would be a tremendous boon to dry process pigment manufacturers. At the February 1956 AIME meeting in New York City a symposium by the Fillers, Fibers, and



Two thirds of E. W. Davis Works is now in operation. Shown here is construction work on the pelletizing plant. Crusher and concentrator buildings are in background.

Pigments Committee raises the curtain on three relatively new aerodynamically designed classifiers that promise to approach this objective. These include a high speed classifier by the **Hurricane Pulverizer Co.**; the Mikroplex air classifier, a high speed close tolerance machine now being imported from Germany; and a newly developed optimal-vortex classifier now offered by the **Sharples Corp.** Design of these machines appears to rely heavily on short residence time, instantaneous classification, and highly developed aerodynamics. If these classifiers stand up to the manufacturer's claim of 80 to 95 pct efficiency compared to a more typical 10 to 80 pct, it should be possible to reduce substantially the cost of fine particle manufacture through the use of less expensive dry processes without sacrificing the quality which thus far has been possible only through wet processes.

Cyclones are being used for desliming and preparing feed for Humphreys Spirals at the Harrison plant at the **M. A. Hanna Co.**, while the use of cyclones as classifiers in regrind circuits has been hampered by undue wear on pumps. William Arpi of **Pilotac** seems to have eliminated this trouble, but at Morenci and Hurley difficulties are still being experienced, although cyclones will at least take over primary mill classification on sulfide ores. The evidence presented at Las Vegas by Idarado and Morenci was too good to be ignored, for as compared to conventional classification they give about 20 pct thicker pulps to flotation, which results in less water and more retention time in the float cells. They also provide better mineral distribution in the flotation feed, lower pH in lime circuits, and cause floc breaking.

During 1955 there has been a spectacular rise in the use of flocculating agents for solid-liquid separation as applied to thickening and filtering. All types of mills have found uses for flocculants, and, due to faster settling and filtration rates, there have been many beneficial results, such as increased mill capacity and lower cake moisture.

A new pulp density scale has been developed by the **Mine & Smelter Supply Co.**

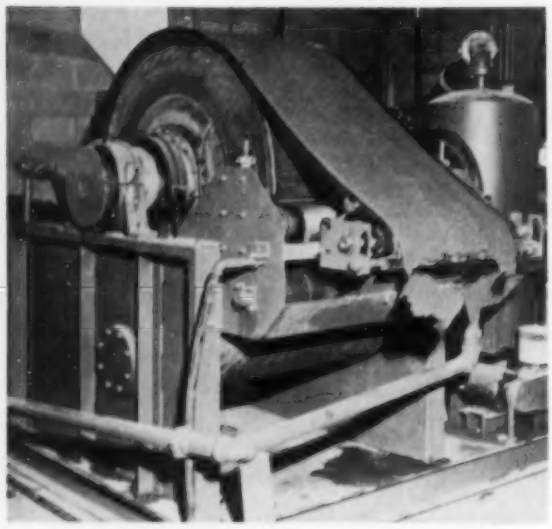
Increasing importance of leaching in the flowsheet has pointed out the value of high efficiency in vacuum filters to recover the last bit of pregnant liquor from the sands. **Eimco** at its Palatine, Ill., Research & Development Laboratories has announced outstanding results from the Eimco Burwell filter that is being proved in the uranium leaching field. Another filter that has proved its worth this year is the Eimco Rotobelt, which has a self-aligning belt-type filter medium. With this filter there is no chance for blow back of leach liquor; cake recovery as thin as 1/16 in. is allowed. Also, there is a spectacular reduction in necessary time for change in filter medium, from 4 to 8 hr on the conventional drum-type filter to 10 min on the Rotobelt.

Coal washing screens are being used in heavy media separation to obtain the benefit of the action of water sprays to set up a whirling, swirling motion in the pool. The clockwise rotation of material in these pools results in a scrubbing action, which in addition to agitation removes much of the fine media adhering to the surface of the material, so that it can be recovered for re-use. These coal washing features will greatly increase the percentage of media recovered in preparation plants.

This year it has been proved that long service life of the screen cloth with low maintenance costs can be obtained on Thermo-Deck screens. These screens handle successfully such materials as limestone containing up to 3.7 to 4 pct surface moisture. In many cases it has been shown that for material which cannot be screened conventionally the heated deck is the only possibility. One operator claimed that there was a saving of approximately 13¢ per ton through use of the heated deck screen compared to drying the material and using a conventional screen.

A new screen, designed to handle hot sinter, will be offered on the market in 1956. It is to follow the post sintering crusher and handle sinter in the range of 900° to 1500°F. It is spring supported, and the vibrating mechanism and motor drive are mounted underneath the screen to keep them out of the heat zone. An outstanding feature of the screen is that the deck is composed of panels that can be removed easily when a section burns out.

Hewitt-Robins has announced sales of a new modified resonance screen to run at higher efficiency than any other. **Deister Concentrator Co.** has offered on the market for the first time its Model E Leahy vibrating screen with a new method for screen cloth mounting and tensioning. The screen, previously offered in 4-ft widths, can now be furnished in 5-ft widths, with Flex Elex method for electrically heating the screen cloth. According to



The Eimco Rotobelt Filter, which has a self-aligning belt-type filter medium, proved its operating efficiency during 1955.

the manufacturer, Flex Elex has substantially reduced power consumption over the regular electrical screens. The **Derrick Mfg Co.** has announced a high speed, lightweight screen that is being used in several localities. It is claimed to have a much higher screening rate than other screens and to be practically free from blinding. Tests at Tahawus indicate that separations can be made efficiently as fine as 80 mesh wet with little or no blinding.

Mill Design

Mill construction for 1955 was booming after somewhat of a breathing spell in 1954. The start of the first section of **Reserve Mining Co.'s E. W. Davis Works** was probably the highlight of the year. The **Erie Mining Co.'s** plants are still scheduled to start production in 1957.

Mill design and layout is finally receiving the recognition it deserves. This is due to the fact that large tonnage plants treating low grade ores involve large capital expenditures, and a saving in manpower and in unit costs can be a deciding factor in success or failure of an enterprise.

Automation in new mills is still to be fully developed, but major mill designers caution their clients that simplicity in layout and construction is a much more important consideration. Costs of mill construction are rising along with the general economy. New machinery and methods keep the designer ever aware of progress.

Materials Handling

Of all the unit processes covered by MBD, materials handling probably demands more creative ability on the part of the designer than any other. In spite of attempts being made to put this vital function on a scientific basis today, the designer skilled by experience in materials handling is the *prima donna* of the profession.

Conveyor belts, bucket elevators, pumps, screw conveyors, chutes, screens, drag lines, and many other such devices have always been considered fundamental pieces of handling equipment, but this year the Aerofall mill has entered the picture because of the possibility of taking a primary crusher product down to the size of liberation in one unit. Thus many hundreds of feet of transfer equipment can be eliminated from the flowsheet.

Crushers so designed that mechanical advantage augments gravity flow of materials through the crushing chamber are being developed. They will allow increased reduction ratios and will require less head room. Hence the number of stages of crushing can be reduced, thereby reducing the magnitude of the transfer system.

A great deal of work is being done by a major manufacturer on bucket elevator design aiming at an installation that will be competitive in large scale materials handling.

At **Anaconda** a new crushing system has been installed at the railroad yards. A belt carries the crushed ore up to the concentrator and eliminates the long haul of railroad cars up to the highline.

Concentration

Although leaching techniques hold the spotlight in concentration this year, much spectacular work is being done in flotation, both from a theoretical as well as a practical standpoint. From Montana, D. W. McGlashan and his group have introduced an improved contact angle apparatus for flotation research. Gaudin, de Bruyn, Fuerstenau, and their group at MIT reported on their studies of collector adsorption and on ionic size of flotation collectors. Arbiter and his group at Columbia have, according to reports, solved a problem of floating chrysocolla on a foreign ore by a technique that can be applied universally to ores of the oxidized type. S. R. B. Cooke and his team have made great strides in their search for effective collectors for hematite. For flotation men the $64,000 question remains: Who will come forward with a collector specific to earthy hematite?

This year there was a tapering off of experimentation on magnetic separators as contrasted with last year's competitive pressure to develop the best separator to be used for certain steps in taconite concentration. The use of Alnico permanent magnet appears to be growing, and in capacity respects, the trend is toward more feet of width at moderate field intensities rather than super high intensities in smaller machines. It has been speculated (Haskins of **Dings Magnetic Separator Co.**) that in the future, permanent magnets may supplant electromagnets throughout for the beneficiation of taconite.

Carpco Engineering Co. has announced many successful applications of electrostatic and high density magnetic concentrators of heavy minerals. One of the new developments of the year was the introduction of the Carpco Fanning ore concentrator which makes a gravity separation, utilizing stream flow, with no moving parts.

Deister Concentrator Co. announced that the super duty diagonal deck concentrating table is now equipped with a new Concenco head motion which follows the proved basic design of older head motion but includes some mechanical changes. Improvements have also been made in the Concenco distributor line, particularly by splash proofing it with live rubber sheet.

Details of the manufacture and properties of ferrosilicon for heavy media separation were given by F. Rodis at the Goslar, Germany, meeting. With equal pulp density and equal screen analyses, heavy liquids containing spherical particles are of lower viscosity than heavy liquids containing particles that are not spherical. Conversely, for equal vis-

cosity, a density of only 3.1 to 3.2 using normally ground ferrosilicon can be increased to 3.45 with atomized ferrosilicon and to as high as 3.9 using a special grade ferrosilicon consisting of ball-shaped particles only. No operating results from large plants using a density as high as 3.9 are available yet, but a suspension of 3.45 density is now being used in a large plant. The spherical shape and smooth surface of atomized ferrosilicon lead to a reduction in heavy media losses.

Concentration of Materials Other than Natural Ores, presented by H. Rush Spedden at Goslar, stated that in order to get from extremely complex ores a product suitable for mineral dressing methods, it has been found desirable to alter the contained minerals. Alteration may be achieved by such techniques as smelting to produce a mixture of synthetic materials or by partial reduction to a mixture of metals and minerals or to a mixture of metal and slag. After alteration, normal mineral dressing processes and equipment including flotation, roasting, leaching, the Aerofall mill, the ball mill, and electrostatic separation can be used. Wastes also constitute a material other than natural ores from which metals may be removed. Substantial amounts of aluminum, cryolite, titanium, magnesium, and silver are being recovered by this technique.

Following the lead of the U. S. Bureau of Mines, investigators in several laboratories are studying selective reduction in the solid state to metal in combinations such as ilmenite and chromite. Under controlled reducing conditions the iron is sweated out on to the surface of the mineral particle. Differential grinding followed by magnetic separation yields metallic iron and a nonmagnetic residue of titanium or chromium oxides.

Solution and Precipitation

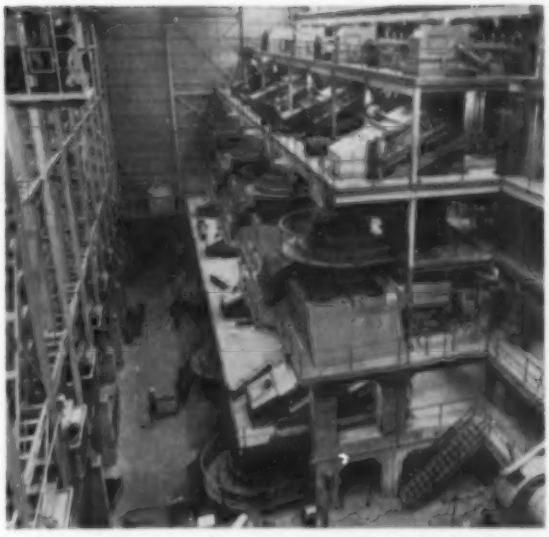
The history of solution in beneficiation began in the early 19th century. In 1887 discovery of the cyanidation process not only revolutionized gold recovery, but also set the pattern for the solution techniques being used today wherever leaching is required in the process flowsheet.

The trend of using high pressures and temperatures for leaching continues, but many problems have been encountered. Herb Rose reports that the search continues for a valve that will stand up to the rigors of discharging pulps from high pressures to atmospheric pressure. Chemical and mechanical erosion of vessels and the design of seals are examples of other sources of difficulty.

A new leaching technique that reduces the leaching time of an ore from 48 hr to 10 min has been reported from a Western operation. This phenomenal reduction in time permits treating lower grade ores.

Although various reagents are being used for solution during leaching and for reduction of substances from pregnant liquors during precipitation, new plants have one thing in common: they depend largely on flocculating agents for the success of their treatment operations. It is reported that practically all new uranium mills are being designed around the use of flocculating agents in all their solids-liquids separations.

Use of flocculants such as Separan, Jaguar, Guartec, and Lytron has speeded up precipitation to the extent that much smaller thickener and filter areas are needed. Filter rates from 30 to as high as 80 lb per hr per sq ft are being obtained. For flocculating reagents, operators report a cost between 10 and 15¢ per ton of dry ore. According to D. A. Dahlstrom filter rates on the flocculated material decrease rapidly with time. Flocs are fragile and must be handled rapidly but gently. To do this job, **Eimco** has marketed a flocculator designed for a maximum 2 min retention time. The flocculating agent is added to the slurry at the intake of the machine and the flocs overflow into a launder that feeds the filter.



Cone crushers reduce 3-in. taconite to —¾-in. ahead of first milling stage at the E. W. Davis Works of Reserve Mining Co.

Allis-Chalmers has marketed a continuous extraction column for leaching ores by countercurrent flow methods. **Dorr-Oliver Inc.** has acquired marketing rights to the Merrill-Crowe cyanide precipitation and regeneration process.

Pyrolysis and Agglomeration

Bethlehem and **Erie** shaft furnaces will vie with **Reserve** and **Cleveland-Cliffs** traveling grate plants for pellet production honors. The Erie shaft furnace for heat hardening has doubled capacity of two years ago, principally through improvements in the inside contour of the furnace, better chunk breakers, and more air blowers. Reserve uses the downdraft method of firing and Cleveland-Cliffs uses the updraft deep bed method.

Cleveland-Cliffs is building an agglomeration plant for ores, from the Republic mine, which will start about Apr. 1, 1956, producing concentrate by a froth flotation flowsheet similar to that at the Humboldt mine. Two thousand tpd of concentrates will be burned by an updraft traveling grate process. The plant, to be located on the railroad a few miles west of Marquette, will be in production this year.

A new **International Nickel** plant has installed the first disks in North America for pelletizing iron ore on a commercial scale. However, much work has been done in the research laboratories in the various parts of the country on this type of pelletizing device. Also during the year the first pellets were shipped from **Bethlehem Steel's** Marmora plant in Ontario.

Research and development of a process for cold hardening of iron ore pellets is being carried on. An aqueous solution of sodium silicate is added to the concentrate before balling, and after balling, the pellets are cured in an atmosphere of carbon diox-

ide. With a similar technique a small amount of hydrated lime is added to the finely ground concentrate, and after balling the pellets are cured in carbon dioxide. Agglomerates from these treatments are as hard as the heat hardened product.

Blast furnace operators, seeking to increase production rates and reduce coke rates, are looking toward the crushing and sintering plant to give them sized ores for direct charging plus clean sized sinter. The use of up to 100 pct sinter is being talked of seriously and test runs have been giving encouraging results.

This year saw completion of three new sintering plants. The plant at **Weirton Steel Co.**, Weirton, W. Va., is designed for production of 2000 tpd of sinter from Labrador fines, on an 8-ft wide machine, the first of its kind in the U. S. The plant of **Steel Co. of Canada,** Hamilton, Ont., is built according to certain European practices that in many respects differ from American practices. The plant of **American Steel & Wire Div.,** Cleveland, is one that was moved from a location in the Adirondacks and put into operation at Cleveland in 1955.

A start was made on the building of two new sintering plants during 1955. The one for Fairless Works, **U. S. Steel,** Fairless Hills, Pa., will have an initial capacity of 4000 tpd, mainly from Venezuelan fines. The new plant to be built for **Sheffield Steel Corp.**, Houston, Texas, will have a capacity of 1400 tpd and will operate on the fines from a bedded mixture of Mexican and Texas ores. U. S. Steel is also expanding its sintering capacity at Houseville, Youngstown, and Gary.

In Belgium **Société Générale Métallurgique de Hoboken,** leading nonferrous producer, is completing a new sintering plant with two modern Dwight-Lloyds, which replaces an older plant containing several circular table and straight line machines. In regard to ferrous producers, **Cockerill-Ougrée** and **La Providence** firms in Belgium are considering additional sintering equipment, as are the **de Wendell** interests in France.

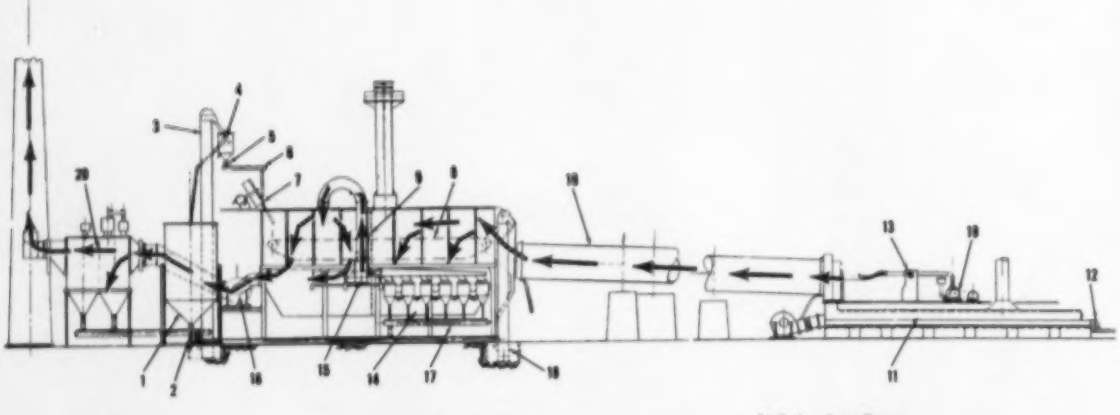
Noranda Mines Ltd. in Canada has turned to sintering to produce sulfur dioxide and high grade iron sinter from pyrite concentrates. An additional installation for the production of sulfuric acid is planned in one of the uranium producing areas. **International Nickel Co.** has completed its first successful year of operation on the oxygen-flash smelting process for smelting fine copper sulfide concentrates.

Cement makers are watching the new double pass preheat system that promises big heat economies, high cleanliness, and small space requirement, which is known as the ACL **(Allis-Chalmers Lellep)** kiln. The inventor of the process is O. G. Lellep, who also developed the first workable downdraft grate hardening process for treating iron ore pellets. The installations will not seem mysterious to operators expert in heat treating of iron concentrates. This plant is to get a tryout by **Marquette Cement Mfg. Co.** and will be installed in the heart of Milwaukee. Installations of this type have been used in Europe and in only two other places in the U. S. It is estimated that the Btu consumption of heat per barrel will be reduced by at least 33 pct. Dust production will be well under the limit set by the City of Milwaukee, which is very strict about air pollution. By use of the ACL kiln system the length of kiln will be reduced 50 pct over that used in the conventional dry process. The preheating system will consist of a moving grate 80 ft long to handle pellets at 12 pct moisture. Gases from the kiln will pass through partially dry pellets and completely dry them on the grate. Before passing to the atmosphere, the gases will be passed over an electrostatic precipitator for final cleaning.

Mineral Review

Iron: During 1955 research on beneficiation of *nonmagnetic taconites* (other than specularite) and other low grade earthy hematites has been intensified. The search for flotation reagents having sensitivities specific to hematite continues concurrently with studies of heat-treating techniques on hematite-to-magnetite reduction in kilns and FluoSolids reactors.

The nonmagnetic taconite from the country's inland empire, estimated in terms of billions of tons, differs in general from the naturally magnetic taconite in that



1. Feed bin.
2. Screw conveyor from kiln feed bin to feed elevator.
3. Feed elevator.
4. Screening spiral conveyors, to remove tramp oversize.
5. Rotary feeder.
6. Vibrating conveyor.
7. Pan-type pelletizer.
8. ACL traveling grate.
9. Baffle, separating drying and burning sections of ACL grate.
10. ACL kiln.
11. Air quenching clinker cooler.
12. Clinker hammermill.
13. Master control panel for ACL kiln department.
14. Cyclone dust collectors.
15. Fan No. 1, for first pass of gases through grate.
16. Fan No. 2, for second pass of gases through grate.
17. Screw conveyor for dust.
18. Elevator returning grate fall-through to kiln.
19. Primary air fan.
20. Electrostatic dust collecting system.

Sketch of the ACL (Allis-Chalmers Lellep) Cement Kiln. This new double pass, preheat system, promises big heat economies, high cleanliness, and small space requirements. An ACL kiln is being installed at the Marquette Cement Mfg. Co. in Milwaukee.

The world's largest lithium producing plant was completed during 1955. It is operated by the Lithium Corp. of America at Bessemer City, N. C.

mesh of liberation may be finer and iron content higher. Conventional reducing roasts to convert the hematite to magnetite, followed by conventional magnetic separation, often do not give satisfactory grades and recoveries simultaneously. Usually the silica content of the concentrate is high. In some cases this can be attributed to nonliberated micron-sized iron particles disseminated throughout the jasper, which, after reduction and magnetization, are attracted into the concentrate. In other cases it can be attributed to entrapment of the silica resulting from differences in the initial magnetic permeability or the retentivity of magnetism of the artificial magnetite as compared to natural magnetite. Investigations of extremely fine grinding and changes in magnetic separator design are being carried on in several laboratories.

An example of the problem of liberation is shown by one of the mineral-bearing horizons in Michigan that contains hematite particles, many of which fall in three relatively narrow size groups. The coarsest particles are predominantly 150 to 200 microns, the next predominantly 35 to 45 microns, and the finest particles 3 to 5 microns. Incidentally, anywhere from 10 to 20 pct of the iron values may be in the finest micron size range. However, following a reducing roast in a FluoSolids reactor, some of the hematitic ores can be stage-ground, with intermediate magnetic separation, down to a size that will yield a satisfactory grade and recovery.

This summer a patent was issued to L. A. Roe (assigned to **Jones & Laughlin Steel Co.**) on a magnetic reflux classifier that makes a true middling product. The middling product can be reworked to satisfy the process specifications.

Republic Steel's pilot plant at the **Spaulding mill** near Birmingham is reported to be trying to make something out of Jefferson County's enormous reserves of low grade iron ores, especially ferruginous sandstone. Trial runs are being made on a reduction roast that goes somewhat beyond artificial magnetite but possibly not all the way to sponge iron. This approach is also being tried on the Minnesota and Michigan hematites with considerable success. Both the kiln and the FluoSolids reactor are being used in these researches for the reduction step.

Studies are being made on solid-stage diffusion of iron oxides, particularly of the finely disseminated and the fine grained hematites. Solid state diffusion of iron atoms has been recognized under reducing conditions, and there is evidence that there is a similar type of diffusion during the reduction of hematite to magnetite. Under carefully controlled reducing conditions there can be a migration of the molecules and a coalescence which results in grain growth.

The new Michigan Tech State laboratory, recently completed, will start active operations sometime in 1956 on research problems related to high grade iron ore and copper ore.

The **E. W. Davis Works**, with a rated capacity of 3.75 million tons of pellets per year, started initial operations. With experience of the **Babbitt plant,** operators are estimating that a somewhat higher tonnage will be produced after the bugs have been worked out of the operation. The Babbitt plant has been producing good pellets during the year using the downdraft heat hardening machine.

In the **Reserve mine** there is considerable variation of magnetic iron content of the ore. Control of grind, important in maintaining grade of concentrate, is accomplished by regulating the quantity of magnetite in the rod mill feed. This is done by means of an electrical coil that passes around the feed conveyor and measures the magnetic field produced by the ore. A similar device is installed in the ball mill circuit just ahead of the Dorr-Clone classifier to maintain constant pulp density. The device has resulted in good classification, has relieved overloading of the ball mill, and has maintained a more uniform grind. This equipment was invented in the Mines Experiment Station at the University of Minnesota.

The **Kaiser Steel Corp.** at its **Eagle Mountain mine** during the past year has been operating a beneficiation plant consisting of dry magnetic separation, followed by heavy media treatment of ⅛ by ¼-in. ore. The installation of facilities for wet magnetic separation, jigging, and cyclones for treating the ¼-in. by zero ore is contemplated.

Cyclone plants on the Range appear to be operating well, but there is a controversy raging at present between advocates of cyclones and of jigs for treatment of the −¼-in. material. There are good and bad points for each, and the decision appears to be based on the relative weight put on each of these points by the individual operators. In cyclone plants there is a trend toward more and smaller cyclones and more magnetic separator capacity. Some of the cyclone plants that have been particularly troubled by contamination of their medium with magnetite from their ore have solved this difficulty by installation of magnetic separators ahead of their feed preparation screens. No solution has been forthcoming to the parallel problem of contamination of ferrosilicon medium by magnetite.

M. A. Hanna started construction of a washing, heavy media, and cyclone plant at the Parcel Tree mine near Coleraine, and has installed a washing plant at the Morton mine. **Pickands, Mather** announced the planning of a new concentrator for the Mahoning mine to consist of a washing, heavy media, cyclone, and spiral plant. This plant should be ready for operation in 1957. **Cleveland-Cliffs** is planning to add a cyclone section at the Canisteo operation, and **Jones & Laughlin** expects to add a jig section at the Hill Annex.

Operations are continuing at **Pilotac** and **Extaca** without any significant changes. At Pilotac the flowsheet experiments are being made by close-circuiting the fourth stage of crushing and also by trying three-stage grinding with magnetic separation after each stage. An additional stage of magnetic separation has been added immediately after the ball mill, making an arrangement similar to the **Erie** and **Reserve** flowsheets. **Oliver** plans shortly to try cyclones as the classifier for closing ball mill circuits to compare them with the hydroseparator and reclassification now being used. Some success has been experienced with the refractory problem in the kiln at Extaca, and approximately 130 days of continuous operation have just been completed. The previous longest continuous run was 63 days.

The Oliver Iron Mining Div. started up the **Arcturus plant** (formerly Gross Marble heavy media and cyclone plant) to treat the wash concentrates from an older plant. The addition consists of two conventional heavy media sections and two cyclone sections. The plant was run for a few weeks this fall to get a better start for next spring and to make some changes during the winter that have been found necessary. The heavy media separation-cyclone installation at the **Arcturus plant** is Oliver's first heavy media plant.

Continued laboratory work on *froth flotation* by both **M. A. Hanna** and **Pickands, Mather** is reported to be leading up to 50 to 100 tpd pilot plant units. One process definitely will float the iron and at least one favors floating the silica away from the limonitic minerals. Rumors of large-scale pilot plants for flotation of wash ore tailings still persist, but no public announcement has yet been made. Continuous pilot plant flotation tests are being made at Hibbing on sink and float and cyclone tailings. If successful this may lead to the installation of a 50-tph flotation plant at the **Tioga No. 2 mine** for the recovery of iron now being lost in porous limonitic ores of that area.

During the year **Rhude & Fryberger** began operating the new Troy wash plant. This plant is novel in that natural magnetite is recovered from the washer tailings, and a hammermill is used to disintegrate the chunky ore. The only other hammermill known to be used on the Range failed because of extreme wear when taconite contaminated the ore.

In the lean ore field west of Grand Rapids **Pickands, Mather** put the Tioga into operation. It is similar to the West Hill plant and contains conventional washing and cyclone concentration sections. The Bennett plant, a smaller version of the Tioga plant, also started operation. At the Danube concentrator near Bovey a heavy media unit was added to treat the $+\frac{1}{4}$-in. fraction of the lean ore. All the $-\frac{1}{4}$-in. material is treated in Conset jigs. The **Erie** commercial plant construction continued to progress and placing of the 54 rod and ball mills is expected soon with a production scheduled for 1957.

M. A. Hanna reports that in two plant installations for treating classifier overflows Krebs two-stage cyclones were used in place of hydroseparators. These devices are reported to be giving a good account of themselves. The underflow of the Krebs cyclones are concentrated on spirals. **Pickands, Mather's** laboratory test work on fine mesh screening has been continued but is not, as yet, completed. Work is also being done on continuous specific gravity recorders.

As in other ore dressing fields, work with chemicals for flocculation of tailings and for the dispersion of slimes in heavy media circuits is being carried on.

The Gilbert Concentrator of **W. S. Moore Co.** at Mariska mine, Gilbert, Minn., is under construction, but there are no plans at the present time for the treatment of fines. A Telesmith Scrubber has been installed in the circuit.

Uranium: The year 1955 marked intense activity in the uranium processing industry. Construction was started on four new mills located at Edgemont, S. D.; Moab, Utah; Tuba City, Ariz.; and Maybell, Colo. During the last part of November negotiations were completed for another new mill to be located at La Sal, Utah. Completion of these five new mills together with expansion of many of the existing mills on the Plateau will bring to 14 the number of processing plants operating in western U. S. It has been estimated that milling capacity this year should double the capacity of the last and that it should double again next year. The plants on the Plateau cost about $10,000 per ton of daily capacity. Production in several new Canadian plants is expected during 1956.

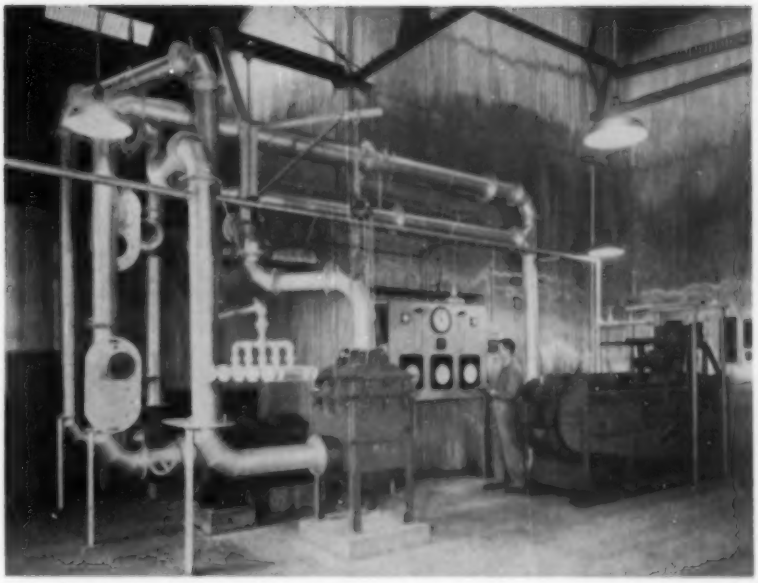
Nearly all the new mills being constructed will use either the resin-in-pulp process or ion-exchange columns. The resin-in-pulp process will generally use acid circuits with nitrate elution. The column exchange plants will use either nitrate or chloride elution. Precipitation will be by conventional means. Much work is being done in the laboratories using solvent extraction for recovery of uranium from either slurries or clarified solutions. In this process one of the phosphates such as tributyl phosphate or dodecylphosphoric acid is used as a solvent in a kerosene or toluene carrier. The uranium may be stripped from the organic with hydrochloric acid and precipitated with ammonium.

In August the AEC declassified all uranium ore processing information involving treatment of ores for production of uranium concentrates. Treatment of concentrates for production of uranium metal and uranium salts remained classified information, but during early November the AEC invited proposals from private contractors for conversion of uranium concentrates to either UF_4 or UF_6.

From the Florida district it has been announced that starting with commercial phosphoric acid containing uranium in solution, the first successful approach has been solvent extraction. Early flowsheets used conventional gravity and pressure mixer settling tanks or columns for mixing and separation of the aqueous-organic phases in compartments with countercurrent flow. The maintenance of a clear phosphate solution to prevent an unusual emulsion formation at the aqueous-organic interphase proved to be a major operating difficulty in view of the supersaturated complex phosphate system. To overcome some of the problems such as filtration of large volumes of in-process materials, James A. Barr, Jr., suggested that high speed centrifugal separation be tried in the highly acid and corrosive system. The problem was overcome, and now uranium is extracted satisfactorily by solvents from phosphoric acid with equipment operating at 6000 rpm and having separating forces at more than 7000 gravity equivalents. Rated capacity of the equipment, which occupies only 60 cu ft, is approximately 200 gal per unit. This is a remarkable application of high speed equipment in a system where application would normally be considered next to impossible due to chemical corrosion, erosion, and solids abrasion. Separation of aqueous phase from organic phase is reported to be complete and clean. Two solvent extraction plants in Florida have been completed and a third is in progress.

Reference should be made to the new tonnage discovery of uranium in the Blind River District of Ontario and the two big mills that are under construction or well advanced in planning. In fact, **Pronto Uranium Mines Ltd.**, the first large, privately owned uranium plant in the Blind River District, went into production four months ahead of schedule.

Two mills are being designed for the Bicroft area, a 1000-ton plant for Bicroft and a 750-ton plant for Fara-



As a part of the intensified research on sintering techniques, the Koppers Co. Inc. opened its American Ore Reclamation Agglomeration Laboratory at Swissvale, Pa., during 1955.

day. Both have provisions for expansion. The **Gunnar mill** started up one ore line in August and the final line in September. Gunnar was designed as a 1250-ton plant and is already doing more than the rated capacity. It started up in record time and with a minimum amount of trouble.

Lithium: American Potash & Chemical Corp. owns 60.1 pct of **American Lithium & Chemicals Inc.** This company is building a $6.5 million plant near San Antonio to process lepidolite from Bikita, Southern Rhodesia, the world's largest high grade deposit of lepidolite.

Kings Mountain, N. C., is boiling with expansion. **Foote Mineral** was the first one in there, but **Lithium Corp. of America** completed a $7 million lithium chemical plant at Bessemer City, N. C., in 1955.

The *CIM Bulletin* has noted several important discoveries of lithium ore in Canada. The chief discovery is that of **Quebec Lithium** at Barraute, Que. This deposit is in production and the sales contract in the U. S. is being expanded. A new discovery of potential importance is in northwest Ontario.

Manganese: A new manganese extraction process has been developed by Bruce Williams and W. S. Stringham of the **Bruce Williams Laboratories** in Joplin. This work has reached the pilot plant stage and a company known as **Ore Beneficiation Inc.** has been formed to operate the pilot plant, which will be constructed with Government financing. This is a chemical process involving low temperature roasting and leaching with precipitation of the manganese as a carbonate. It is designed to be effective on manganese slags and all types of manganese and iron manganese ores.

The USBM reports a successful pilot plant dithionate process for the leaching of manganese dioxide ores. A 200-tpd pilot plant at Riverton, Minn., is using the Dean carbonate leach.

Two heavy media plants to operate on manganese ore started production in central New Mexico during 1955. The **Manganese Corp. of Arizona** replaced its 400-tpd unit with one heating 2500 tons of ore per day, and the **Tower Mining & Refining Co.** went into production at 400 tpd. In spite of a disastrous fire in 1954 and a labor dispute in 1955, **Three Kids** has evolved a flotation mill reported to be one of the neatest of its kind.

Copper, Lead, and Zinc: Initial sections of the new 32,000-ton **San Manuel Corp.** mill at San Manuel, Ariz., started up about October 1. The White Pine operation is substantially completed and is now processing 9200 tpd. Walter Hamilton has reported great success with oversize mills and subsequent flotation. **The Anaconda Co.** has substantially expanded its mill capacity for the treatment of low grade copper ores from the Butte District. A new 225-ton lead-zinc mill of **American Smelting & Refining Co.** at Crested Butte, Colo., started operations in June. **Pima Mining Co.** is planning the construction during 1956 of a mill to treat at least 2000 tons of copper ore at its mine near Tuscon, Ariz.

In Canada operations were initiated in 1955 at **Gaspé Copper Mines Ltd.** and **Campbell Chebougaman Mines Ltd.** The milling of **West Macdonald** ore was undertaken in the mill of **Waite Amulet Mines Ltd.**, where a separate circuit has been installed for its treatment.

The **Paragsha concentrator of Cerro de Pasco Corp.**, Peru, has enlarged from its former capacity of 600 to 1000 tpd. The **Toquepala property,** to be operated by the **Southern Peru Copper Corp.,** is being designed to handle 30,000 tpd. **Vulcan Mines Co.** has increased capacity of its Ticlio, Peru, concentrator to 1100 tpd. **Compañia Minera Atacocha** is also expanding its lead-zinc mill at Chicrin, Peru, to 1100 tpd. **Compagnie des Mines de Huaron,** Peru, is building a new mill to increase its tonnage of lead-zinc ore to 1200 tpd.

The year 1955 marked the startup of the largest copper operation in the Far East. The new **Atlas Consolidated Mining & Development Corp.** copper project on the island of Cebu in the Philippines started up with an initial capacity of 4000 tpd, and the operation will soon be expanded to 6000 tpd.

Tungsten: The **Getchell** Tungsten mine again operated at a capacity of 1200 tpd. During 1954 a boiler was installed to control flotation pulp temperatures, thereby permitting an improvement in metallurgy with lower reagent costs. A temperature range of 74° to 78°F is maintained at all times.

Nevada-Massachusetts continued milling approximately 600 tons of tungsten ore per day throughout the year. Main metallurgical effort was directed toward an increase in tonnage by substitution of screens for classifiers. This change also decreased overgrinding or sliming.

A 400-tpd mill was put into operation at the **Linka mine** at Austin, Nev., by **Consolidated Uranium Mines Inc.** of Salt Lake City. The mill employs straight flotation followed by an acid leach to upgrade the concentrate.

Other Minerals: There has been an increasing industrial appetite for high temperature alloys for jet engines and similar applications. In addition, there is a major trend in the chemical industry toward high temperature reactions which call for heat-resistant

alloy containers. Steam and gas turbine design is now limited by the availability of high temperature metals. Such metals require increasing quantities of molybdenum, tungsten, columbium, and tantalum.

In the semiconductor field other elements are making themselves known now that germanium has taken the lead. Silicon and, to a lesser extent, selenium are included. Germanium requirements are being met by utilizing flue dust that formerly went to waste. There is much more in sight as a byproduct from American operated foreign mines.

Three major discoveries of columbium-tantalum ores, mostly of the pyrochlore type have been publicly announced in Canada this year. These are in the **Oka District** near Montreal, now controlled mainly by **Kennecott Corp.** and the **Molybdenum Corp. of America**; the **Lake Nipissing area** near North Bay; and the **Chapleau area** in Ontario. An important domestic development is that of **Porter Bros.** black sand dredging operation in Bear Valley, 120 miles northeast of Boise, Idaho. The sand is treated in diaphragm jigs to make a concentrate of the heavy minerals. The jig concentrate is split in Porter's new mill at Lowman, Idaho, by a combination of magnetic and electrostatic methods. The main product from the mill is euxnite, which is a complex columbium-tantalum-uranium mineral that will require subsequent chemical processing to separate the values. Associated minerals from the Bear Valley deposit are monazite, magnetite, ilmenite, garnet, and zircon.

There have been cutbacks in titanium production because of an oversupply. **Republic Steel's** important discovery of rutile in the **Oaxaca District** of Mexico has considerably changed the raw material situation because rutile is a more favorable mineral than ilmenite and was hitherto not available in any quantity except from Australia.

Evolution of chemical processes for the recovery of nickel and cobalt continues. Processors have had their troubles with the ores and with the equipment, but **Sherritt Gordon** is now in production. Although **National Lead's** technical development at Fredericktown has been impeded by labor strife, **Calera's** refinery at Salt Lake City is now nearly at full capacity. In the laterite field the **Nicaro plant** is in full operation and being expanded while **Freeport Sulfur** has a 50-ton pilot plant at New Orleans working on another Cuban ore.

International Minerals & Chemical Corp. will soon complete its commercial feldspar beneficiation plant using electrostatic processes. The company has also begun construction of a plant for reclaiming mica from silt behind **Davy Crockett Dam,** Grenville, Tenn. **Synthetic Mica Corp.,** subsidiary of **Mycalex Corp. of America,** recently opened a synthetic mica plant in New Jersey. This is the first operation in this country to be operated solely for the production of synthetic mica.

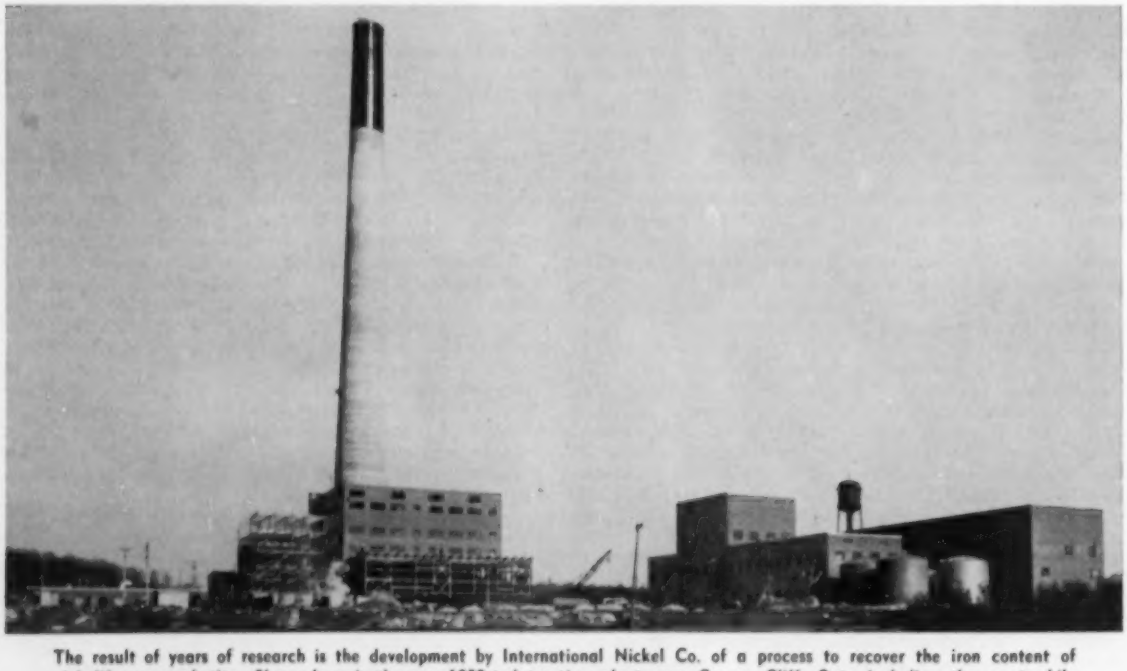
In the phosphate industry the latest innovation to be reported this year is the work sponsored by the AEC to develop the aluminum-phosphate leached zone as a source of alumina, phosphate, and uranium. Unusual separations have been made in the micron size ranges to separate minerals into concentrated fractions. The minerals are apatite, wavelite, millisite, pseudowavelite, kaolinite, and quartz in the size range of 30 mesh to 1/10 of a micron.

Two new potash recovery mills will be built soon in the **Carlsbad** area. The **National Potash Co.** is designating a plant to produce about 400,000 tons of potash salts a year, and a joint company organized by **Farmers Union, Kerr-McGee Oil Industries,** and **Phillips Chemical Co.** is also planning a big operation in the area.

It has been definitely established now that the **Anaconda Aluminum Corp.** can and will produce alumina from the clays of the Pacific Northwest. During the year Anaconda started up at Columbia Falls, Mont., a 120 million lb per year aluminum plant that uses power from the new Hungry Horse Dam.

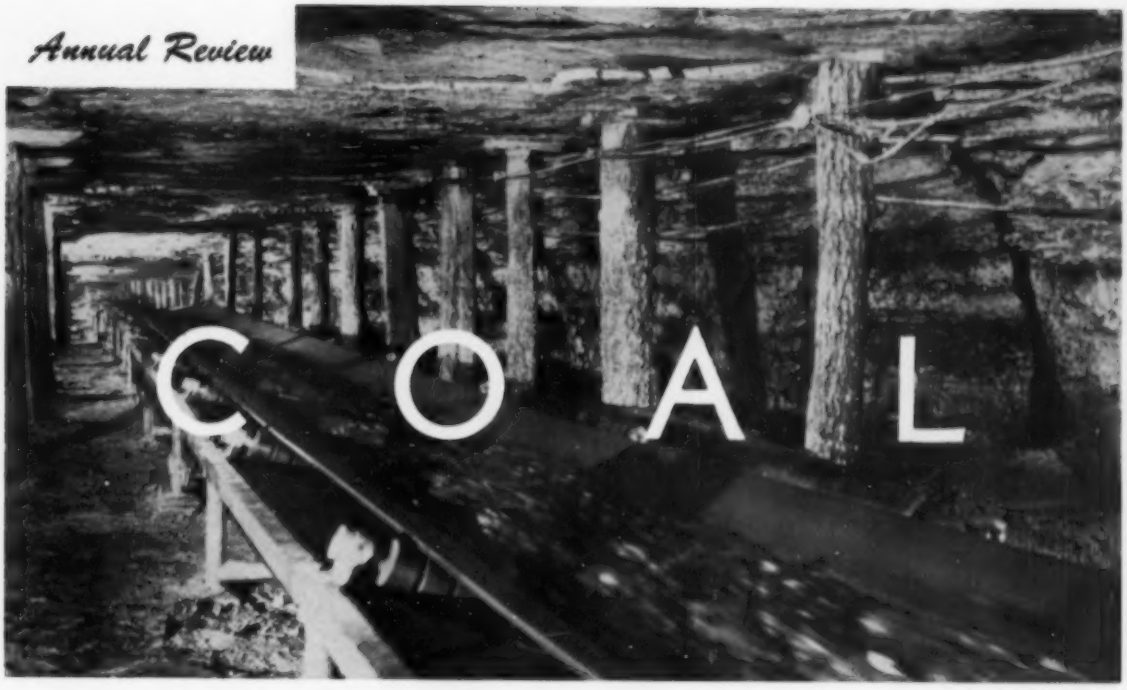
Interest has continued in the U. S. in the use of froth flotation for the production of low iron silica sands for the glass industry. Two plants got underway this year, one in New Jersey and another in California.

On the foreign scene, a 275-ton sulfur flotation concentrator of **Sociedad Azufrera Aucanquilcha** at Ollague, Chile, went into operation early this year, and Johns-Manville opened the second largest mining and milling operation in Southern Rhodesia. The mine is to be operated by the **Rhodesian Asbestos Corp.** and is supposed to treat 125 tons of asbestos ore per hr.



The result of years of research is the development by International Nickel Co. of a process to recover the iron content of nickeliferous pyrrhotite. Shown here is the new 1000-tpd treating plant near Copper Cliff, Ont., including the roaster-kiln building, and at right the ammonia leaching and recovery buildings.

Annual Review



Edited by
H. F. Yancey

Application of continuous mining to thin seams

Larger and more efficient strip coal machinery

Further increase in coal preparation plants; new equipment

New petrographic techniques applied to marginal coking coals

New coal fired power plants to supply AEC and industry

THE coal picture in 1955 was much brighter than in 1954, when the tonnage produced dropped to the 1939 level. *Bituminous coal and lignite production are expected to approach 465 million tons,* against 392 million tons in 1954, an increase of about 19 pct. On the other hand, the production of anthracite declined about 7 pct to some 25 million tons.

There was marked improvement in coal consumption in all industrial lines except railroads. At the end of November 1955 the largest consumer, electric power utilities, had used about 126 million tons, an increase of some 22 million tons over the previous year. Coke-oven consumption increased about 19 million tons and coal coked in beehive ovens increased about 1.5 million tons, due to heavy coke demand accompanying the increased steel production. Railroad consumption, continuing to be affected by the change-over to diesel, was down about 2 million tons. Retail dealer deliveries decreased 1 million tons. All estimates are for 11 months.

Along with these increases in production, which were not matched by improvement in prices or realization, there was a wage increase of $1.20 a day effective September 1, with 80¢ to be added Apr. 1, 1956, resulting in an average shift wage of $22.50 for miners in mechanized mines.

The important and well publicized International Conference on the Peaceful Uses of Atomic Energy held last August at Geneva, Switzerland, brought forth new optmistic reports on the long-range use of radioactive elements as fuel for generating power. Nevertheless, in the immediate future the Atomic Energy Commission itself will continue as a major user of electrical energy from coal, with two new coal-operated power plants, consuming 7.5 million tons a year, located on the Ohio River to supply the AEC. Informed sources consider that the accelerated rate of growth in electrical consumption will

H. F. YANCEY, 1955 Coal Div. Chairman, is Chief of the Div. of Solid Fuel Technology, Region I, U. S. Bureau of Mines, Seattle. J. W. WOOMER is a Consulting Mining Engineer in Wheeling, W. Va. H. B. CHARMBURY is Associate Professor, Mineral Preparation Div., Pennsylvania State University, University Park. JOHN F. BARKLEY is Chief Coal Technologist, U. S. Bureau of Mines, Washington, D. C.

The Goodman Type 500 twin boring continuous miner is an example of the type of highly mechanized machinery bringing pressure for continuous haulage and systematic maintenance in coal mines.

absorb future power produced from nuclear sources without affecting the market for solid fuel.

For the present coal's determination to dominate the electric-energy picture by extending its *mine-mouth* cost advantage over competing fuels is shown by the 110-mile pipeline from Georgetown, Ohio, to the Cleveland area, now under construction. A favorable trend for future coal consumption is foreseen with the purchase of large blocks of coal lands as energy sources for such important power-consuming industries as aluminum. There may well be a shift of these operations from areas in the West, where cheap hydroelectric power has been available, to coal reserves nearer Eastern market centers. A new development for cleaning −¼-in. coal is the modern feldspar jig being installed by Northwestern Improvement Co. at Roslyn, Wash. The present design of this kind of jig, which has not been used in the U. S. for more than 50 years, has been greatly improved through continued development and use in France and Belgium.

A new unit of coal and ore treating equipment that will have an impact, perhaps as great as the Driessen solid-liquid cyclone, is the *sieve-band*, a gravity bar screen that separates on a plant-scale smaller sizes (down to 100 mesh or finer) than are now possible. It was developed by the same laboratory as the cyclone—the Mining Research Laboratory of the Dutch State Mines, Heerlen, The Netherlands. Description of these and other world-wide advances in coal treatment were reported in September 1955 in the *Proceedings of the Second International Coal Preparation Congress*. Copies of papers and discussion in English are available (90 marks, about $21.35) from the Steinkohlenbergbauverein, 2 Friedrichstrasse, Essen, Germany.

Mining

by J. W. Woomer

Increased production was the feature of the year, but equally important were the following quieter, but none the less virile, activities: a) resumption of heavy purchases of production and preparation machinery; b) a noticeable impetus in the institution and continuance of educational and training programs at all levels of the labor force; c) increased recognition of the need for better facilities for transportation, even by pipeline; and d) further attention and study being given to U. S. lignite reserves.

Coal mining appears to have emerged from a somewhat erratic experimental era into an atmosphere of a determined knowledge of its goals. In underground mining the advances in use of continuous miners has brought about a need for further servicing the face so as to insure continuous haulage, continuous and effective maintenance, foolproof communications, better roof control, and positive and systematic safety. Increased attention is being given to the application of continuous machinery to the production of coal from thinner seams.

Recent purchase and application of larger and more efficient strip coal machinery, including the development of the big stripping wheel, is indicative of the maintenance of the present position of this method of coal mining.

The coal industry is gratified by a pronounced trend to the use of coal equipment in the mining of ores and industrial minerals. The hard rock men appear to have admitted that the coal mining technology has moved forward rapidly in a quest for higher yields per man day.

Preparation

by H. B. Charmbury

Coal preparation has continued to play an important role in the industry in 1955, since the increased demand for higher quality coals for combustion and coking has made preparation a must in many areas. In addition, many companies have had to mine reserves of lower grade, and mechanical mining methods have also been a factor. Finally, increased efficiency and higher recovery of both coarse and fine coal are receiving attention. Thus approximately 300 million tons, or about 60 pct of the total production, passed through well over 600 preparation plants in this country during the past year. Should the increase in preparation continue at its present rate practically all coal will be mechanically cleaned within the next ten years.

Although more coal is cleaned in jigs than in any other type of equipment, there has been an increase in the use of dense-medium process for cleaning coarse coal and concentrating tables for finer sizes. Pneumatic methods of coal preparation have also become more important. Equipment has become available to clean coal over a wider range of sizes, with sizes up to 14 in. being cleaned in heavy-medium vessels.

Improvements have also been made in the crushing and screening of coal. There has been increased use of a rolling ring type of crusher for obtaining larger reduction ratios with the minimum amount of fines. Screens of stainless steel construction to prevent corrosion are now available with centralized lubrication to save labor cost and a wide variety of surfaces for every specific job. Within the past year, the first 8-ft wide vibrating screen was installed.

Increased public demand for prevention of air and stream pollution has created problems for the designers of coal preparation plants. West Virginia, Pennsylvania, and Kentucky, which have 60 pct of the country's coal preparation plants, now have stream pollution laws regulating discharge of acids and solids into the streams. Ohio, Missouri, Colorado, and Montana are now considering similar legislation, and operators throughout the country are keeping a watchful eye on the Federal Government's interest in pollution. As a result of this, dust collection, thickening with and without flocculants, filtration, centrifuging, drying, and the use of cyclones have been added to older plants and included in newer designs.

Utilization

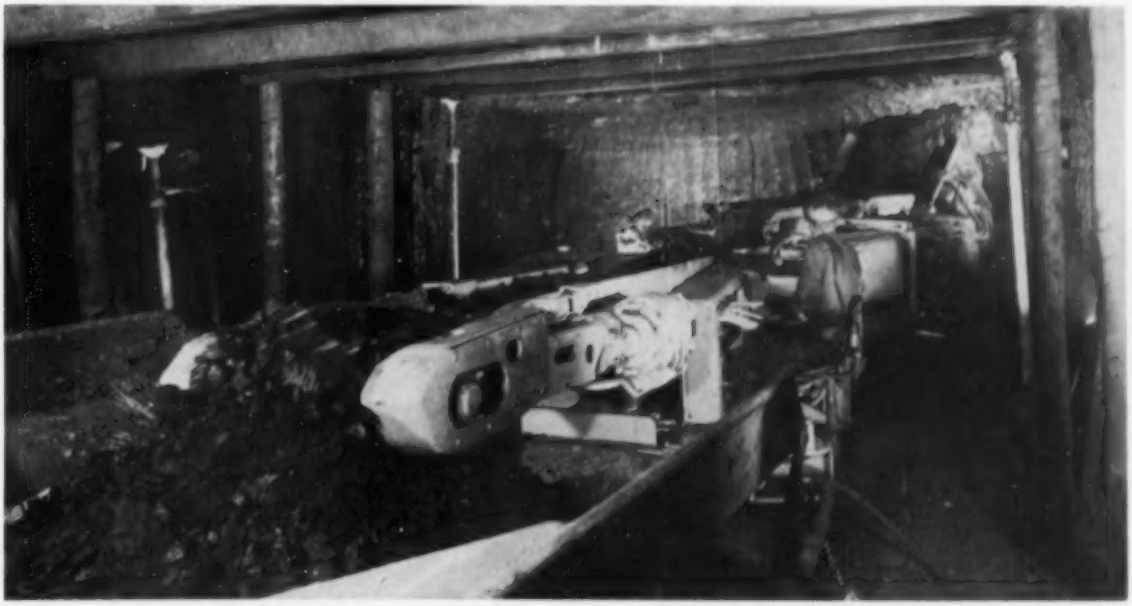
by John F. Barkley

Combustion: During 1955 vibrating or oscillating grate stokers were introduced by several manufacturers due to the claimed dual advantages of lower cost and less dust emission. Some installations used direct hopper feeding to the grate, and others were used in conjunction with a spreader stoker.

Extensive laboratory and field studies were conducted to determine the cause of fire-side boiler deposits. Valuable basic information uncovered may lead to reduction of this power plant problem.

The Bureau of Mines is expected soon to publish studies of the burning of coal in thin fuel beds. This work will provide additional knowledge of the reactions occurring in traveling grate and crossfeed type stokers.

Carbonization: Recently there has been much interest in applying new techniques of petrography to improve carbonizing behavior of marginal-type coking coals. For more rapid plant control analysis, petrographic comparisons are made by reflected light instead of the thin section technique developed by Thiessen. Promising results have been obtained in laboratory study of the blending of fusible with nonfusible compounds of the same coal, and it is reported from Germany that application of this new



Coal mine mechanization is being steadily pushed forward. Here the Joy 1-CM Continuous Miner finishes cut in face and discharges into a shuttle car.

About 60 pct of U. S. coal production passes through preparation plants. This plant in eastern Kentucky is one of the 600 preparation plants in operation.

laboratory technique to industrial operations has increased the yield and quality of coke.

Recent work at the Bureau of Mines indicates that large improvements in the coking behavior of marginal high oxygen poor coking coals can be effected by heating the coal in an essentially inert atmosphere at temperatures below the fusion point of the coal.

A development originating in Europe is that of utilizing iron ore fines to produce a *ferro-coke*. A recent paper given before the AIME discussed results on the manufacture and use of ferro-coke in which about 30 pct by weight of iron ore (5 pct by volume) was incorporated in a coking mix. A similar line of work is the manufacture of a ferro-coke briquette by a modification of the Disco Process in which an iron ore and coal mixture is treated in a rotating oven. It is reported that this briquette can be handled without substantial breakage.

Gasification: A commercial-size unit for the gasification of pulverized coal in entrainment at atmospheric pressure by means of oxygen and steam has been built by the Babcock & Wilcox Co. for E. I. du Pont de Nemours & Co. and put in operation early in the year at Belle, W. Va. Construction of another commercial-size unit for the gasification of finely granulated coal at high pressure by means of oxygen and steam at the Morgantown ammonia plant was announced by Olin Mathieson Chemical Corp. This gasifier, developed by the Texaco Development Corp., incorporates a feeder in which a slurry of the granulated coal and water is fed through an externally heated coal where the coal undergoes a size reduction. The water is converted to steam which serves as a medium for transporting the coal to the generator.

The Bureau of Mines and the AEC jointly initiated development of a suitable reactor for synthesis gas production. Several chemical firms also have been engaged in making independent evaluations of the feasibility of employing atomic heat for chemical processes among which the production of synthesis gas from coal is outstanding. Further research work on catalysts and apparatus for converting synthesis gas to high Btu has been continued by the Institute of Gas Technology and the Bureau of Mines.

Air and Water Pollution: During the last year considerable activity has developed in both the problems of air pollution and stream pollution. In the former, the question of sulfur dioxide, in addition to smoke and fly ash, is receiving increasing consideration. With the rapid growth in steam electric generation, many communities are pressing for closer studies of the make-up of the gases discharged from chimneys.

A number of processes for the removal of SO_2 have been suggested and some have been in operation with modifications for a number of years. Absorption of SO_2 from flue gas by means of a dry reagent has been attempted but presents serious difficulties. One other system which shows promise consists of treating flue gases in scrubbers using a solution of anhydrous ammonia. The ammonium sulfate so formed is recovered as fertilizer. The feasibility of oxidizing flue gas SO_2 by means of ozone was investigated by Bituminous Coal Research Inc. Results of this study indicated it to be technically possible but not economic, and the study is being directed toward other approaches.

The two great problems of stream pollution as far as the coal industry is concerned are acid mine water drainage and suspended solids from wet coal cleaning and preparation plants.

Research on mine acid drainage, underwritten by the coal and steel industries, is being continued at the Mellon Institute of Industrial Research. Experiments are also being carried on throughout the watershed of Little Raccoon Creek in Ohio. This latter is a joint project sponsored by the State of Ohio, the coal industry through the Ohio Reclamation Assn., and the Mellon Institute. The suspended solids accompanying waste washery discharges are receiving increased attention due to pressure from several state regulatory agencies.

Nonfuel Uses: Studies in the vast field of nonfuel uses of coal were continued and progress was made in improving present techniques. Research toward development of new chemicals and uses was carried forward.

Important advances are being made in the output of coal stripping operations. Here the Zacherl Coal Co. is stripping near Clarion, Pa.

Annual Review

Mineral Industry Health And Safety, 1955

by S. H. Ash

WITH statistics still incomplete, it appears that the safety record of the mineral industry for 1955 will do well to hold its own in comparison with 1954. On the one hand, metal mining shows an improvement in its record, due in part to intensive campaigns for preventing ground fall accidents. Coal mining, on the other hand, is showing a poorer record in 1955 than for the preceding year. While no major disasters occurred during the year, increased fatalities resulted from ground fall, haulage, and machinery accidents. It seems probable that increased job training may serve to improve the situation.

Health: Utilization of diesel equipment continues to increase in noncoal mines, in spite of existing prejudice. In 1955 two types of diesel-driven tractors and one shuttle car were approved by the USBM. Where diesel engines are used controlled ventilation is mandatory in order to keep the CO content under 20 ppm, but such ventilation is not difficult to achieve with normal equipment.

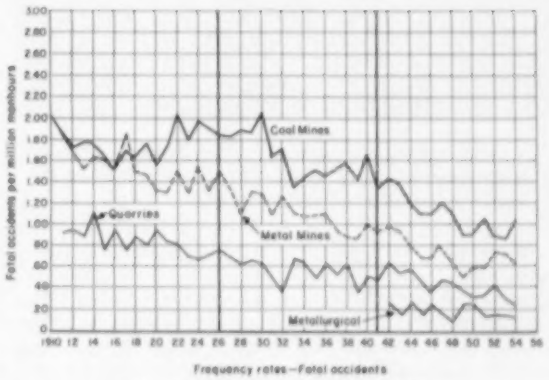
Preventing dust disease has always been a problem, and despite all the good work done to control silicosis in metal mines, this disease is now costing the industry more than ever before. Moreover, because of the demand for key alloying materials to withstand extremely high temperatures, ores that increase dust problems are now being mined. Nevertheless, given necessary equipment and workmen with sufficient instruction, it is apparent that dust can be controlled.

Ventilation of uranium mines requires particular care because some uranium ores are highly siliceous and all give off toxic radon gas. It appears that work should be done on the adoption of safety and health standards relating to mining of uranium ores.

The long-time dream of effective, generalized mine lighting appears to be at least one step closer to realization. For some years the USBM has been testing various types of equipment, and a schedule has now been formulated on approval requirements for mine-lighting equipment.

Control of Ground Falls: Rock bolting continues to be the most successful procedure for reducing the injury rate from ground falls; nevertheless, wood-timbering is by far the most commonly used method for supporting loose rock. Ground falls are the source of most mine accidents, and more than one third of the fatal injuries from roof falls can be traced to the failure of conventional timber or roof bolts dislodged or destroyed by blasting. Numerous avoidable roof fall injuries will continue to occur unless supervisors make replacement of supports after blasting mandatory.

S. H. ASH is Technical Assistant, Office of Assistant Director, Health & Safety, USBM, Washington, D. C.



Trend of fatal injury rates since 1910.

Haulage & Hoisting: Fatalities from haulage accidents rank second in the list of causes. In addition, haulage and hoisting accidents generally cause greater economic loss than any other type of mine accident, except fires, for they usually interrupt production and often cause considerable property damage. Losses from such accidents clearly justify an effort to reduce hazards.

The USBM has just issued Miners' Circular 53, *Accidents From Hoisting and Haulage at Metal and Nonmetallic Mines.*

Fires & Explosions: Mine fires can be exceedingly dangerous because of restricted operating space, difficulty of approach, the presence of combustible materials, and the mineral itself, which may be highly combustible. Increased use of belt conveyors has heightened the problem of mine fires, and a disastrous fire from a belt conveyor in the Creswell colliery in England, causing 80 deaths, focused the attention of all segments of the mineral industry on this hazard. Upon investigation by the USBM it was ascertained that over 50 such fires had occurred in the few years conveyors have been used to any extent in American coal mines. The Bureau conducted extensive investigations of fire-resistant conveyor belts. Tests were made on more than 100 samples of conveyor belting from 30 manufacturers in the U. S. and abroad, and a schedule of requirements and tests was established for USBM acceptance of conveyor belts as fire-resistant.

By 1953 over 600 miles of conveyors were in use in 322 coal mines throughout the U. S. Since then the number in use by both coal and noncoal mines has greatly increased.

This self-propelled Joy RBD-15 drill has been developed to speed rock bolt installation. Rock bolting continues to be most successful means of reducing number of injuries from ground falls.

Fires and explosions in air-compressor systems have been known to occur ever since the high-pressure reciprocating compressor was developed. The Ontario Mining Assn. and the Ontario Dept. of Mines conducted a world-wide investigation of fires and explosions in air-compressor systems in mines. Results indicate that overheating of damaged or broken valves is associated with the vast majority of the accidents and that all fires and explosions occurred in connection with reciprocating air compressor systems.

Floods: Adjoining abandoned mines that have become filled with water are a menace to operating mines in several localities. Experience confirms the belief that inaccurate plans or maps or their absence has been the primary cause of the largest number of accidents caused by flooding. Neglect and errors in judgment also figure as important causes.

Disasters: No major disasters occurred in the mining industry during 1955; nevertheless, there were some serious inundation accidents in the coal mines. In one of these four men lost their lives.

Fatal-Injury Rate: Although the mineral industry in 1955 will have a lower fatal-injury rate than in 1954, it will not be below the 1952 rate (0.59 per million man-hr) because of the higher rate in coal mines.

On Apr. 26, 1955, 483 Certificates of Honor for outstanding safety records and 14 Medals of Honor and 4 Certificates of Honor for heroic acts were awarded to organizations and individuals in the mineral industries.

Above-Ground Operations: Both the number and percentage of fatal injuries occurring outside mines is increasing, because strippings and opencut methods are increasing both in employment and tonnage. Although the hazards on the whole are less, the exposure is reduced, and the injury rates are somewhat misleading. It is noteworthy that carelessness in blasting practices is increasing. Statistics indicate that a better job of accident prevention is being done underground than in surface works.

Safe operating practice for reciprocating air compressors as given by Bawden and Moore are as follows:*

1. Provision should be made for draining any valleys in the compressed-air system, if valleys cannot be avoided.

2. Intake air should be clean and cool.

3. Compressors should be equipped with thermometers for measuring air temperatures after leaving the low-pressure cylinder, intercooler, and high-pressure cylinder.

4. Cylinder lubricating oil should be a mineral oil having a naphthalene base carefully checked for suitability.

5. Valves, coolers, receivers, and connecting piping should be examined at regular intervals and cleaned often to prevent deposits of carbonaceous material from accumulating. Worn piston rings should be replaced to prevent leakage.

6. Aftercoolers are recommended as essential to good operation.

7. Electrical power cutoffs may be installed to cut off the power should the air temperature in the compressor rise abnormally.

8. Pipelines should be firmly suspended to prevent vibration.

9. A compressor should not be allowed to operate "off load" for long periods.

10. Regular inspections should include examination of all water passages.

* Based on world-wide research by R. K. Moore for the Ontario Mining Assn. and W. E. Bawden for the Ontario Dept. of Mines.

Depolarizing Magnetite Pulps

by M. F. Williams and L. G. Hendrickson

IN classification of pulps bearing magnetized ferromagnetic particles, depolarizing is of great importance. If size separation is to be effective, particles must be individual rather than in flocs. Depolarizing is also practiced in heavy medium separations in which ferrosilicon or magnetite is the medium.

When particles of ferromagnetic material have been removed from a magnetic field, residual magnetism causes agglomeration. The term *depolarizing* refers to the operation of reducing or eliminating this residual magnetism and may thus be considered *magnetic deflocculation*. The terms *demagnetizing* and *randomizing* are also used.

At the Research Laboratory of Oliver Iron Mining Div. in Duluth a method was developed for measuring depolarization of the pulp of ferromagnetic material. Experiments were made with Mesabi taconite,[1] a natural magnetite of low coercive force. Ferromagnetic materials of higher coercive force, such as lodestone or the artificial magnetite produced by reduction roasting of hematite, present a more difficult problem, which was not within the scope of this investigation. It is possible, however, that some of the techniques evolved for measuring and calculating electrical characteristics of alternating current coils would be of use in depolarizing high coercive force material, particularly in conjunction with high-frequency alternating current, as proposed by Hartig and others.[2, 3]

Properties of Ferromagnetic Materials:[4-7] Experimental work, described below, has shown that if a sample in the magnetized state is heated above the Curie point and cooled, much of the preferred orientation is destroyed and the sample is substantially depolarized. It has been thought that when the sample cools below the Curie point the domains cancel each other, leaving a zero net moment. However, such particles still exhibit a tendency to cohere, and undoubtedly this is caused by the forces of residual magnetism. As measured by the *percent depolarization*, this tendency is reproducible for any sample upon repeated heating above the Curie point and subsequent cooling and is independent of the initial state of magnetization. It is postulated, therefore, that as the material is cooled below the Curie point the domains in any particle do not completely cancel each other, but rather are preferentially oriented to some extent.

Mechanism of Depolarizing with Alternating Current Magnetic Fields: It is believed that when ferromagnetic material is passed through an alternating magnetic field, depolarizing occurs in the decaying portion of the field. As the particles pass through the portion of highest intensity they become magnetized. If the particles are not free to move, the polarities of the particles will be reversed (by a mechanism similar to that described above for magnetism) at a frequency equal to that of the applied field. As the material moves through the decaying field, intensity levels become such that a domain does not completely reverse, but stops on an axis of easy magnetization. By the time the material reaches the point of zero field intensity, a state of fairly random orientation of domains is achieved. If conditions are such as to give a completely random orientation, the particle will have little or no external magnetic field, and a pulp of such particles will be *depolarized*.

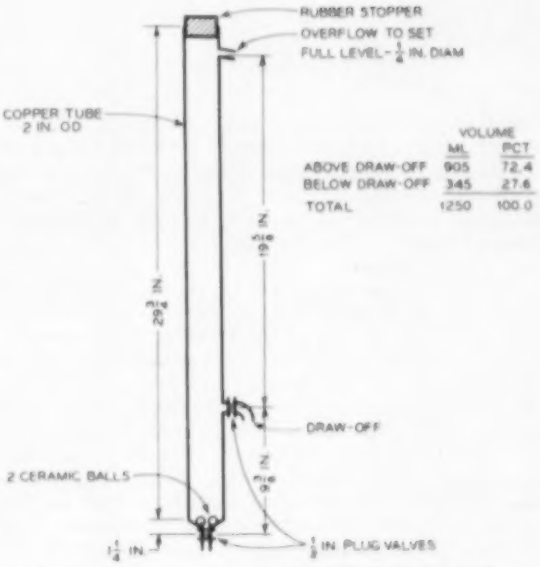


Fig. 1—Apparatus for measuring depolarization of magnetite.

Previous Work

In 1918 E. W. Davis was granted a patent for demagnetization of magnetite pulps.[8] His method consisted of passing the pulp through a tapered coil, activated by alternating current of normal frequency (60 cycle). This method, with minor modifications, has been used almost universally in all pilot plants and commercial installations in which depolarization of low coercive force materials has been required.

Hartig, Onstad and Foot[2, 3] have made a detailed study of the factors involved in depolarizing both low (below 100 oersteds) and high (above 100 oersteds) coercive force material. They developed a method for evaluating the relative degree of depolarization of any pulp based on the settling characteristics of the pulp. Their standard of comparison was a sample heated to above the Curie point and cooled in a zero field, all in a neutral atmosphere.* For low coercive force material they found that results equivalent to Curie treatment could be

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Discussion of this paper, TP 4199B, may be sent (2 copies) to AIME before April 30, 1956. Manuscript, Oct. 15, 1954. New York Meeting, February 1955.

* This procedure is subsequently called, in this report, the *Curie treatment*.

The Transactions papers appearing in Mining Engineering during 1956 will subsequently appear in AIME Transactions Volume 205 and may be permanently referenced to that volume.

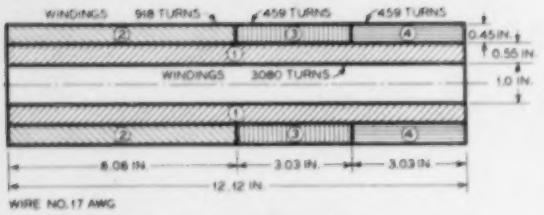

Fig. 2—12x1-in. coil.

obtained by introducing a pulp of the material into a 60 cycle a-c field of 550 oersteds (effective or root mean square value), allowing it to remain in this field for several seconds, and then slowly withdrawing. This slow withdrawal method, being much simpler than Curie treatment, was used as the standard of comparison.

Using this evaluation technique, the investigators concluded that with static conditions, substantially complete depolarizing of low coercive force material could be obtained: 1) with field strengths of 425 to 500 oersteds, rms; 2) without any finite time in the maximum strength portion of the field; and 3) with rates of flow such that the rate of decay of the field in any particle does not exceed 15 to 25 pct for any alternating cycle. With flowing pulps, they found that depolarizing was less complete than in the static state, but this effect could be overcome by increasing the field strength, for example, from 500 to 700 oersteds, rms.

Experimental Work

Evaluating Effectiveness of Depolarizing: Evaluation methods previously used were unsatisfactory for this work because gangue particles made it difficult to observe the settling rate of the magnetite. To overcome this objection, modifications were made to measure settling rate of the magnetite only. With this method the criterion of depolarizing was the *slow withdrawal* from an 800 oersted (rms) a-c field. The present work substantiated the findings of Hartig that slow withdrawal from a field of 550 oersteds or more was equivalent to depolarizing by the Curie treatment.

The apparatus used is a copper tube, 2 in. diam, with bronze plug valves as shown in Fig. 1. A pulp sample containing 50 to 100 g of magnetic material is introduced from the top and the tube is filled with water to the overflow tube, thus giving a pulp

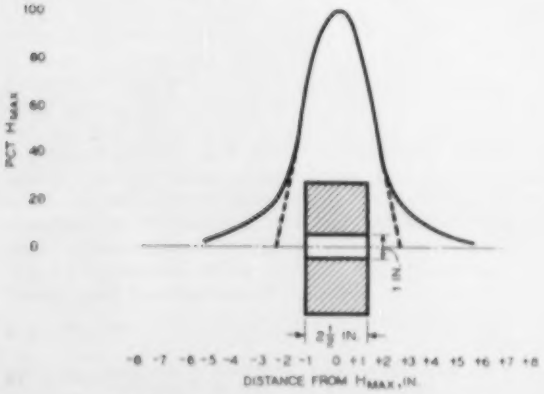

Fig. 3a—2½x1-in. coil; 2500 turns of No. 18 wire.

of 5 to 10 pct solids. It is then stoppered and upended 20 times, with a finger held over the overflow tube, then placed in a vertical position and allowed to stand for 45 sec. At the end of the sedimentation period the draw-off plug valve is opened and the pulp above is collected in a beaker and is called the overflow. The pulp remaining is collected in another beaker and is called the underflow. These two fractions are then separately treated in the Davis tube to recover the magnetic fractions, which are dried and weighed. The two fractions are combined and repulped in about 200 ml of water, after which the pulp is given the so-called 100 pct depolarizing treatment, which consists of placing the pulp in a glass vessel or the sedimentation tube in an 800 oersted a-c magnetic field and slowly withdrawing it. After this the pulp is put through exactly the same series of treatments as the original sample—including sedimentation, Davis tubing, drying, and weighing.

Data are handled as shown in Table I. The weight of magnetic material above the draw-off tube at the start of sedimentation is calculated by multiplying the weight of total solids in the tube by 72.4, which is the percent volume above the draw-off tube. The

Table I. Determination of Degree of Depolarizing

As Is Davis Tube Conc., Weight Grams				Pct Material Initially Above Draw-off Remaining in Suspension Above Draw-off After 45 Sec	
Overflow	Underflow	Total	Above Draw-off at Start		
22.1	55.0	77.1	55.8	39.6	
		100 Pct Depolarized			Pct Depolarized
17.4	59.6	77.0	55.7	31.2	127

percent depolarizing is obtained by taking the *as-is* over the *100 pct depolarized* percent weight in suspension above the draw-off after 45 sec and mutliplying by 100.

The selection of 45 sec settling, which was somewhat arbitrary, was based on the reasoning that 53 microns (270 mesh) was a significant and convenient point of reference in the classification operation. In this particular tube at 45 sec settling time, Stokes law predicts that for spheres the 53-micron material would be equally divided between the overflow and underflow.

The reproducibility of this test was checked by making 12 duplicate determinations of the percent of the material initially above draw-off remaining in suspension above draw-off after 45 sec. The mean of the values obtained was 57.8, average deviation 1.8, and standard deviation 2.1.

This procedure has the following desirable features: 1) A single number describes the degree of depolarizing. 2) Siliceous material, which is nonmagnetic and hence of no concern, is eliminated.**

** Tests indicate that the fact that siliceous material is present in the first sedimentation but not in the second has little or no effect at dilutions employed.

3) Sensitivity and reproducibility are adequate for the purposes at hand.

Measuring Intensity of A-C Fields: Field strengths of the various coils used in the investigation were measured by determining the voltage induced in a search coil calibrated against a standard coil, constructed with a length that was great as compared with diameter and with thin windings (approaching

Table II. Effect of Variables on Depolarization

Test No.	H_{max}, Oersteds, Rms	Pulp Velocity, Fps	Rate of Field Decay Cycle, Pct: Straight Part of Curve	Rate of Field Decay Cycle, Pct: At 100 Oersteds	Time in H_{max}, Cycles	Pct Depolarized	Coil: Designation	Coil: Connection
Effect of Maximum Field Intensity								
13A	200	0.8	8		8.9	110	2½ x 1 in.	
13B	800	0.8	8		8.9	116	2½ x 1 in.	
13C	200	1.3	13		5.5	122	2½ x 1 in.	
13D	800	1.3	13		5.5	126	2½ x 1 in.	
15M	800	2.8	25		28.9	113	12 x 1 in.	1
15N	400	2.8	28		24.0	110	12 x 1 in.	1
15O	200	2.7	27		24.8	107	12 x 1 in.	1
15J	800	16.1	28	182	1.3	34	12 x 1 in.	2
15K	400	15.4	27	108	1.4	42	12 x 1 in.	2
15L	200	15.8	27	28	1.4	62	12 x 1 in.	2
Effect of Retention Time in Maximum Field*								
15P	800	2.6	26		2.7	108	2½ x 1 in.	
15Q	400	2.4	24		3.0	108	2½ x 1 in.	
15R	200	2.6	26		2.8	100	2½ x 1 in.	
Effect of Pulp Velocity and Rate of Field Decay Considered Together								
13A	200	0.8	8	8	8.9	110	2½ x 1 in.	
13C	200	1.3	13	13	5.5	122	2½ x 1 in.	
13E	200	2.6	26	26	2.5	104	2½ x 1 in.	
13I	200	8.4	84	84	0.9	71	2½ x 1 in.	
13Q	200	15.6	156	156	0.5	21	2½ x 1 in.	
13G	200	3.9	10	10	1.8	102	Tapered	
13K	200	7.6	19	19	0.9	92	Tapered	
13S	200	15.6	39	39	0.5	66	Tapered	
Effect of Pulp Velocity at the Same Rate of Field Decay**								
	200	16.4	40	40		64	Tapered	
	200	4.0	40	40		103	2½ x 1 in.	
	200	12.3	30	30		77	Tapered	
	200	3.0	30	30		110	2½ x 1 in.	
	200	8.2	20	20		80	Tapered	
	200	2.0	20	20		118	2½ x 1 in.	

* Compare items here with data for 15 M,N,O under Effect of Maximum Field Intensity.
** Data interpolated from Fig. 4b.

a single layer), the intensity of which can be calculated by the standard formula:*

$$H \text{ axis center} = \frac{0.4\,\pi\,NI}{\sqrt{4R^2 + S^2}}$$

when H axis center equals field intensity, in oersteds, at the center of the coil on the longitudinal axis; N is the number of turns; I is the current in amperes; R is radius of winding, cm; and S is length of coil, cm. In lieu of a standard coil the search coil factor can be calculated from the formula:

$$H/E = \frac{10^8}{2\pi fNA}$$

where H/E equals search coil factor, oersteds per induced volt; f is frequency; N is number of turns; and A is area, cm².

Early Investigation: The importance of effective depolarizing became evident during pilot plant testing of flowsheets for grinding and concentrating magnetite taconite. The flowsheet employed consisted of two-stage grinding (first stage, rod milling; second stage, ball milling) with concentration by magnetic separation following each grinding step. The ball mill was operated in closed circuit with a classifier; since this material was subjected to a magnetic field in the first stage (cobbing) of magnetic separation, depolarizing of the plup was required before classification in the ball mill circuit.

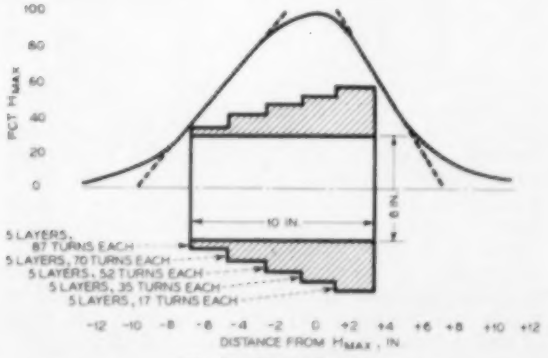

Fig. 3b—Tapered coil.

Carried out under the conditions prescribed by Hartig,* in most of the early tests depolarizing appeared adequate to give desired separation. In some of the tests, however, classification was erratic, and circumstantial evidence indicated faulty depolarizing as a possible cause. As classification is of considerable importance in commercial operation, a thorough review of the factors affecting depolarization was made to determine permissible limits of field intensity and velocity applying to the particular material being tested, and methods were evolved to insure the best possible depolarization for operations at the Pilotac plant of Oliver Iron Mining Div. at Mountain Iron, Minn.

Table III. Drop Tests to Determine Rate of Field Decay

Test No.	Height, H-Ft	Velocity at H_{max}, Fps	Rate of Field Decay Cycle, Pct	Pct Depolarized
20-A	0.5	6	15	97
B	1.5	10	25	102
C	3.5	15	37	99
D	6.25	20	50	98
E	9.75	25	62	97
F	14	30	75	96
G	20	36	90	99

Apparatus: Most of the depolarizing test work was carried out in a closed-circuit system. Pulp flowed by gravity from a steady-head tank through a depolarizing coil and was pumped back through a

magnetizing coil or magnetic separator for remagnetizing, then back to the steady-head tank. All tests were made on a ball-mill discharge (classifier feed) from the magnetite taconite pilot plant. Screen analysis of this product is approximately as follows:

Screen Size, Mesh	Weight, Pct	Cumulative Weight, Pct
+48	8.1	8.1
48/100	14.7	22.8
100/200	31.0	53.8
200/270	12.4	66.7
−270	33.3	

It contained approximately 56.1 pct Fe and 7.6 pct SiO_2. Although magnetic properties were not determined, the magnetite contained is believed to have a coercive force in the neighborhood of 80 oersteds.

Experimental Data

Some preliminary tests were made while experimental techniques were being developed, on the assumption (from Hartig's work) that the most important factor in depolarizing was the rate of decay of the field in the pulp. These tests indicated that although the rate of field decay was important, the velocity of flow had a significant effect over and above that attributable to the rate of field decay. To distinguish between the effect of these several variables, it was necessary to use several coils of different field shapes. Sketches of coils and field shapes are shown in Figs. 2 through 4a.

It will be noted that the coil sketched in Fig. 4a has a variety of possible combinations of windings, allowing a diversity of field shapes. By the use of more than one coil, it was possible to hold all the variables constant except the one under consideration. For instance, the rate of decay in the 12x1-in. coil with connection 1 was approximately the same as that for the 2½x1-in. coil. As the former has a long plateau at the maximum field strength, whereas the latter reaches the peak field only in the coil center, this gave a convenient method for holding all variables constant except retention time in H_{max}. Similarly, the effect of different rate of field decay at the same velocity can be obtained by comparing flow through the 2½x1-in. coil with that through the tapered coil, due to the substantially different rate of field decay in the two coils.

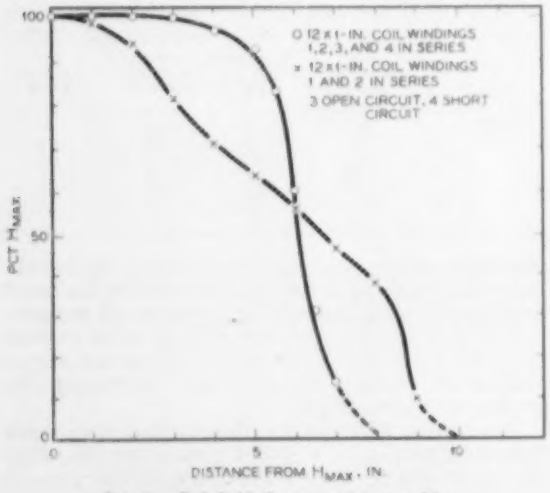

Fig. 4a—Coil field shapes used in test 15.

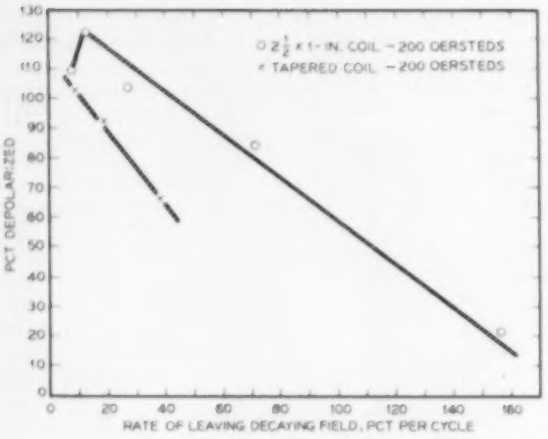

Fig. 4b—Comparative data from tests 13 and 15.

It will be noted that for the coils with a single set of windings (2½x1-in. coil, tapered coil, and 12x1-in. coil, connection 1) the curve of field strength vs distance is a smooth curve of regular shape, whereas for the more complicated connection (12x1-in. coil, connection 2) the rate of field decay changes for different parts of the coil. This introduces the difficulty of evaluating the rate of decay for this type of winding.

For lack of a better method, an arbitrary system for comparing the field shapes was used in most cases. A straight line was drawn tangential to the straight portions of the field intensity-distance curves (see Figs. 3a and 3b) and field gradient was expressed as the slope of this line, in percent per inch. Rate of decay, in percent per cycle, could then be calculated from this figure, the velocity of flow, and the frequency. This system of expressing the rate of field decay is satisfactory for coils with single windings, but not for cases in which irregularities occur in the field shape curves. As will be pointed out below, it appears that the rate of field decay in the region of $H = 100$ oersteds is of particular significance in the depolarization operation, and for tests in which this effect is important the field decay has been measured as the slope of the tangent to the field shape curve at 100 oersteds.

Tests summarized in Table II were planned so that effects of maximum field intensity (H_{max}), retention time at H_{max}, rate of field intensity decay, and velocity could be compared.

Analysis of Data in Table II

Effect of Maximum Field Intensity: For this factor the tests within each group (except the 15 J, K, L group) are similar in all respects except H_{max}. It will be noted that for the first three groups, H_{max} has little effect on depolarizing, with perhaps a slight advantage in favor of high field strengths. The tests of the 15 J, K, L, however, show a significant advantage in favor of low field strengths. These tests were made with the 12x1-in. coil, with the No. 2 connection (irregular field shape). If the rate of field decay here is calculated by the usual method the rates of decay are the same for all three tests. However, if the slope of the tangent at 100 oersteds is used to calculate the rate of field decay, it will be noted that the rates are widely different, the rates of decay being higher for the higher field strengths. This has been taken as an indication that the rate

Table IV. Depolarization by Flowing Through Pipes of Various Diameters

Test No.	Pipe Diam In., Nominal	Pipe Diam Ft, Actual	Pulp Velocity, Fps	Reynolds Number, Re	Pct Depolarized	Remarks
27A	3	0.245	2.14	8910	107	Rather rough entry
27D	3	0.245	2.02	8270	104	
27B	3	0.245	1.54	7080	105	
27C	3	0.245	0.83	3700	113	
31A	3	0.245	1.79	8040	97	Rather rough entry
31B	3	0.245	1.52	6750	117	
31X	3	0.245	0.77	3450	134	
27E	2	0.1615	4.88	15000	99	Rough entry
27F	2	0.1615	3.14	9460	108	
27G	2	0.1615	2.85	8720	100	
27H	2	0.1615	1.47	4400	109	
31I	2	0.1615	4.35	13040	106	Smooth entry
31J	2	0.1615	2.92	8850	105	
31K	2	0.1615	1.06	3190	112	
27I	1½	0.125	8.04	19200	104	Rough entry
27J	1½	0.125	4.90	11700	83	
27K	1½	0.125	3.54	8400	108	
27L	1½	0.125	1.54	3650	126	
31N	1½	0.125	7.38	17800	115	Smooth entry
31O	1½	0.125	3.37	7720	120	
31W	1½	0.125	1.72	4070	127	
27M	1	0.0727	12.82	18300	102	Very rough entry
27N	1	0.0727	7.47	10480	118	
27O	1	0.0727	4.60	6330	110	
27P	1	0.0727	2.62	3700	136	
31Q	1	0.0727	13.31	17700	112	Smooth entry
31R	1	0.0727	6.28	8710	136	
31S	1	0.0727	2.80	3800	136	
27Q	¾	0.0516	11.80	11670	100	Very rough entry
27R	¾	0.0516	6.90	8910	102	
27S	¾	0.0516	5.36	5370	110	
27T	¾	0.0516	2.38	2390	118	
31T	¾	0.0516	11.8	11420	109	Slight ridge at entry
31U	¾	0.0516	7.28	7010	118	
31V	¾	0.0516	2.35	2340	155	

Depolarizing coil: tapered coil, H_{max}, 400 oersteds.
Material: Pilot plant ball mill discharge.
Viscosity assumed to be 0.00612 English units in calculating N_{Re} (0.1 centipoise).

of decay in the region of 100 oersteds is of particular importance.

Effect of Retention Time in Maximum Field: Comparison of the 15 P, Q, R group in Table II with the 15 M, N, O group indicates that with other factors constant there is no advantage in a long retention time in H_{max}.

Effect of Pulp Velocity and Rate of Field Decay Considered Together: It is clear from these two series of tests that with increasing pulp velocity and rate of field decay, other factors being constant, depolarizing is impaired. It will be noted, however, that Test 13A at low pulp velocity was not as well depolarized as would be expected from the general trend shown. This will be discussed later in the paper. The data from these two series have been plotted in Fig. 4b.

Effect of Pulp Velocity: The effect of pulp velocity with other factors (including rate of field decay) constant, may be observed by comparison of the 13A,C,E,I,Q set with the 13 G,K,S set which was made with coils of different rates of field decay. As the experimental conditions were not set to make direct comparisons at either the same velocity or the same rate of field decay, the data have been plotted in Fig. 4b, and the *Pct Depolarizing* at equal values of field-decay rate interpolated from the curves. These data, listed in the last group in Table II, indicate that velocity of flow has an effect over and above that associated with rate of field decay.

In Table II more than half the values cited for *Pct Depolarizing* exceed 100 pct. This means that those samples were better depolarized than by the standard method, i.e., slow withdrawal, equivalent to Curie treatment. The values over 100 pct are surprising, as the Curie treatment was thought to be the ultimate in depolarizing. However, the existence of values over 100 pct has been well substantiated by results from a large number of tests.

Drop Tests on Rate of Field Decay: Still another method was devised to distinguish between the effects of pulp velocity and rate of field decay. A plactic *bomb* was constructed with a set of tail fins, similar to an arrow, so that it could be dropped with accuracy from a considerable height through the 6-in. tapered coil. After a sample of ball mill discharge was placed in the bomb, the bomb was stoppered and dropped through the 6-in. tapered coil from various heights. Thus different rates of field decay could be obtained with zero pulp velocity relative to container walls. Results are listed in Table III. In these tests depolarizing remained at about 100 pct up to a rate of field decline of 50 pct per cycle, and even up to 75 pct per cycle the effect was minor. In no case, however, did depolarizing exceed 100 pct. From these tests it was concluded that

Table V. Extract from Data of Table IV

Test No.	Pipe Diam In., Nominal	Pipe Diam Ft, Actual	Pulp Velocity, Fps	Reynolds Number	Pct Depolarized
31A	3	0.245	1.79	8040	97
J	2	0.1615	2.92	8850	105
L	1½	0.125	1.54	3650	126
S	1	0.0727	2.80	3800	136
V	¾	0.0516	2.35	2340	155

Material: pilot plant ball mill discharge.

1) field decay up to at least 50 pct per cycle was permissible, and 2) some flow of pulp is necessary to obtain depolarizing in excess of 100 pct.

Effect of Conduit Diameter and Significance of the Reynolds Number: In reviewing the data of Table II, it may be noted that in the ⅞-in. ID copper tubing used, substantially complete depolarizing (over 100

Table VI. Effect of Variables in Free-Fall Method

Test No.	Pulp Velocity, Fps: At Orifice	Pulp Velocity, Fps: At H_{max}	Volume Rate, Ft³/Sec	Orifice Diam: Actual In.	Orifice Diam: Actual Ft	Orifice Diam: Effective Ft	Pulp, Sp Gr	H_{max} Oersteds, Rms	Reynolds No.*	Pct Depolarized	Orifices, No.
Effect of Orifice Size											
41F	8.2	9.6	0.0150	5/8	0.064	0.048	1.82	606	7220	134	1
41G	8.2	9.6	0.0606	1 1/8	0.125	0.097	1.82	606	14770	139	1
41E	8.0	9.0	0.1053	2	0.167	0.130	1.82	606	18320	122	1
41D	8.0	9.0	0.198	2 3/4	0.230	0.178	1.82	606	26440	122	1
Effect of Field Intensity											
35J	9.4	10.6	0.0173	5/8	0.064	0.048	1.78	200	8200	99	1
41I	6.9	8.0	0.0614	1 1/8	0.125	0.097	1.80	332	12300	133	1
35B	9.7	11.0	0.0179	5/8	0.064	0.048	1.83	400	8700	131	1
35K	9.1	10.2	0.0177	3/4	0.064	0.048	1.79	800	7980	123	1
Effect of Pulp Density											
43A	8.0	9.0	0.060	1 1/8	0.125	0.097	2.03	446	16080	136	1
43G	9.3	10.1	0.068	1 1/8	0.125	0.097	1.78	446	16390	142	1
42M	9.8	10.4	0.071	1 1/8	0.125	0.097	1.78	446	16920	140	1
43N	9.6	10.4	0.071	1 1/8	0.125	0.097	1.51	446	14360	144	1
43O	9.6	10.4	0.071	1 1/8	0.125	0.097	1.36	446	12930	136	1
Effect of Number of Orifices (without Baffles) and Effect of Feed in Baffles											
46A	8.7	9.5	0.064	1 1/8	0.125	0.097	1.86	446	16030	117	1
46D	7.4	8.4	0.124	1 1/8	0.125	0.097	1.88	446	13780	103	2
46B	8.7	9.5	0.220	1 1/8	0.125	0.097	1.86	446	16030	111	3
Effect of Number of Orifices (with Baffles) and Effect of Baffles in Feed Box											
47B	8.4	10.0	0.062	1 1/8	0.125	0.097	1.73	446	14300	137	1
47C	8.0	9.8	0.118	1 1/8	0.125	0.097	1.76	446	13940	130	2
47D	6.8	8.6	0.151	1 1/8	0.125	0.097	1.73	446	11651	126	3

* At point of discharge from orifice, using effective diameter of orifice.
Depolarizing coil: tapered coil.
In calculation of N_{Re} viscosity is assumed to be 0.00612 English units.

pct) was obtained only when the pulp velocity did not exceed about 7 to 8 fps. In some cases, e.g., Test 13 J, a lower velocity was required, but only when the rate of field decay exceeded 60 to 70 pct per cycle. It was considered possible that this region of rather critical velocity might be related to the transition from streamline to turbulent flow. If this was the case, the Reynolds number should serve as an indication of the transition point and would serve for comparing conditions with varying sizes of conduit. Reynolds number, N_{Re}, is defined as:

$$N_{Re} = \frac{D\,V\,P}{\mu}$$

where D is pipe diameter, ft; V is pulp velocity, fps; P is mass density, lb/ft³; and μ is viscosity in English units (centipoises/1488).

The viscosity of the pulp was not known, but for purposes of comparison a figure of 0.00612 English units (9.1 centipoise), determined from previous work, was assumed.

Assuming this viscosity and a pulp velocity of 7.5 fps in 7/8-in. ID tubing, N_{Re} was calculated to be 8820. For a Newtonian fluid, the transition from streamline to turbulent flow usually occurs in the range of N_{Re} between 1700 and 3700. The exact point of transition varies depending on other factors, such as length of straight conduit, surface roughness, and disturbance of the stream upon entrance. The friction factor has been plotted against Reynolds number in an attempt to determine the transition point between streamline and turbulent flow for magnetite pulps. Such measurements are difficult and uncertain on a pulp of suspended solids, and it was not possible to determine the transition value with any degree of certainty, but the plot seemed to indicate transition in the region about $N_{Re} = 3000$ (assuming the same value of viscosity).

Although $N_{Re} = 8800$ is not in close accord with the transition value at about $N_{Re} = 3000$ so determined, the hypothesis was made that the region around 8000 might still be in the transition zone. In view of the several uncertainties involved, this is not without the realm of possibility.

This hypothesis was checked by making tests at different velocities in pipes of different sizes. Results are reported in Table IV. Table V contains an extract from Table IV, showing the percent depolarization obtained with pipes of different diameters at approximately the same pulp velocities.

In these tests a steady-head tank was used to deliver the pulp to the conduit. In Test 27 the tubes were connected to the steady-head tank by welding to standard pipe bushings, and it is obvious that the entrances would be rough and not conducive to streamline flow. In Test 31 the tube fittings were turned down and somewhat smoothed to favor streamline flow. The data indicate that at equal Reynolds numbers, depolarizing is better with the smoother entries.

Data from Test 31 have been plotted in Fig. 5, showing the relationship between the percent depolarized and Reynolds number. Although there is a considerable scattering of points, this curve shows a definite trend towards better depolarizing at decreasing Reynolds number. The differences in flow conditions due to influences not accounted for in the Reynolds number could well account for the deviations from the curve. It will be noted, too, that most of the points not falling on the line are in the neighborhood of $N_{Re} = 9000$, which may be a critical range in the transition from streamline and turbulent flow.

Discharge Through Orifice and Free Fall Through Coil: The preceding data indicated that streamline flow favors good depolarizing and that if streamline flow prevails (at N_{Re} less than 4000 to 6000) relatively high velocities through the coil can be tolerated. To apply these conditions to pulp flows that might be encountered in a commercial plant, it

would be necessary to use a large number of small tubes, with perhaps several tubes passing through a single coil. This would be an awkward arrangement at best and would require a complex installation. In an attempt to find a simpler method, it was thought that desirable flow conditions might be achieved by allowing the pulp to flow through an orifice and then to pass through an a-c field in free fall. By this method, even if turbulence was set up in the stream in passing through the orifice, it should decrease once the pulp entered free fall. This scheme was tried and found to give excellent depolarizing results, and experiments were made to determine the effect of the several variables on depolarizing. Here again, a closed-circuit system was used, with a steady-head tank feeding the orifice or orifices. In these tests the head in the tank was measured and, using the formula $V = K\sqrt{2gh}$, where V is velocity, fps, h equals head in feet of pulp and K is the coefficient of discharge. This coefficient was found to be 0.60 to 0.65, agreeing well with figures given in the literature for sharp-edged orifices. In calculating N_{Re}, the effective diameter of the orifice was taken as that which gives an area of 60 pct of the actual orifice area. The data from these tests is summarized in Table VI. It will be noted that the values for percent depolarized are very high throughout and, in general, equivalent to the best values obtained by flow through pipes. Good depolarization was obtained with Reynolds numbers as high as 19,000 (at the point of discharge).

The first group of tests (Test 46) in Table VI was made using a simple tank feed box for the orifice, the incoming feed being pumped directly into the pool. For the second group (Test 47) the tank was provided with baffles in such a manner that the pool above the orifices would be much quieter and not disturbed by the new feed. Use of a quiescent pool gave a significant improvement in depolarizing.

The data of Table VI indicate that best results are obtained with orifice diameters of 1½ in. and less, although fairly good results were obtained with sizes up to 2¾ in. Results indicate that multiple orifices can be used successfully, although there is a slight tendency for depolarizing to be poorer as more orifices are used.

The tests reported in the second group of Table VI also indicate that field intensities from 300 to 800 oersteds are satisfactory. An intensity of 200 oersteds appears to be too low. Data in the third group of Table VI show that depolarizing is unaffected by pulp density in the range 35 to 65 pct solids.

Comparison of Flow through Tubes with Free-Fall Method: Table VII contains data from a test made to compare flow through tubes with free fall from an orifice discharge. In the tube tests velocities were maintained at 6 to 7 fps in each test; in the orifice tests, the orifice sizes were chosen so that the effective diameter would be equal to that of one of the tubes. Velocities at the point of leaving the orifice were about 8 fps; at H_{max} the velocities were 5.8 to 9 fps. The data show clearly that depolarizing using orifice discharge and free fall is superior to flowing through tubes of equivalent diameter, particularly at larger stream diameters.

Commercial Installation at Pilotac: As the laboratory tests using free fall from an orifice discharge were so successful, it was decided to use this method at the Pilotac plant of the Oliver Iron Mining Div. This plant consists of three parallel sections for concentrating magnetite taconite, each with a design capacity of 2000 tons crude per day.

To accommodate the expected flow in each section, it was calculated that 28 1½-in. orifices operating under a head of 2 ft would be required. As the cost of a-c solenoids increases exponentially with diameter, it was decided to split the stream between four coils, with seven orifices discharging through each. Orifice plates with seven 1½-in. holes in each were cast of silicon carbide. By arrangement of six orifices on 2-in. centers around a central orifice, the stream could be accommodated within a coil 7 in. I.D. The coils were designed with a field about 16 in. long and with H_{max} about 6 in. below the orifices. Calculated velocity at H_{max} is about 13 fps.

This installation has been in operation since the plant started in June 1953 and has given satisfactory depolarizing. Periodic checks show the pulps to be 110 to 120 pct depolarized, and it is believed that this performance can be improved by making provisions to minimize disturbances in the feed box.

It has not been possible to obtain exact correlation between the effectiveness of depolarizing and classifier performance, but the importance of good depolarization has been demonstrated in a general way at the Pilotac plant.

Two kinds of classifiers are in use at Pilotac, rake and hydroseparator. An overflow containing about 75 pct −270 mesh is desired. Both operate well and give reasonably good size separations when depolarizing is good (110 to 120 pct). With the rake classifier, when depolarizing falls below 100 pct, the rake product changes from a clean granular sand to a jelly-like mass and is difficult to rake up the slope. Magnetic material tends to build up in the pool. After a short time it is impossible to obtain any circulating load.

With the hydroseparator there is no problem removing the sand product as with the rake, but there is difficulty in overflowing the finished material. Particle size of the overflow becomes heavier and more contaminated by fine material. It has also been

Table VII. Comparison of Flow Through Tubes with Free Fall from Orifices

Test No.	Pulp Velocity, Fps: In Pipe or at Orifice	Pulp Velocity, Fps: At H_{max}	Volume Rate, Ft³ Per Sec	Type of Flow Tube or Orifice	Orifice or Tube Diameter: Actual In.	Orifice or Tube Diameter: Actual Ft	Orifice or Tube Diameter: Effective Ft	Pulp Density: Solids	Pulp Density: Sp Gr	H_{max}	Reynolds Number	Pct Depolarized
51A	8.0	9.0	0.0173	Orifice	13/16	0.068	0.053	59.0	1.80	446	7650	145
51B	8.2	9.2	0.0269	Orifice	1	0.083	0.065	65.7	1.96	446	10640	131
51C	7.5	8.5	0.0552	Orifice	1½	0.125	0.097	67.6	2.05	446	15010	133
51D	7.8	8.8	0.0970	Orifice	1 15/16	0.162	0.126	67.7	2.05	446	20430	130
51E	5.8	7.0	0.1130	Orifice	2⅛	0.208	0.161	67.6	2.05	446	18330	134
51G	5.8	5.8	0.0121	Tube	⅝	0.052	0.052	67.9	2.05	446	6380	137
51H	6.3	6.3	0.0195	Tube	¾	0.063	0.062	67.5	2.04	446	8180	150
51I	6.7	6.7	0.0469	Tube	1¼	0.094	0.094	64.4	1.85	446	12390	117
51J	6.3	6.3	0.077	Tube	1½	0.125	0.125	68.7	2.61	446	15960	100
51K	6.0	6.0	0.123	Tube	2	0.162	0.162	67.6	2.05	446	20160	98

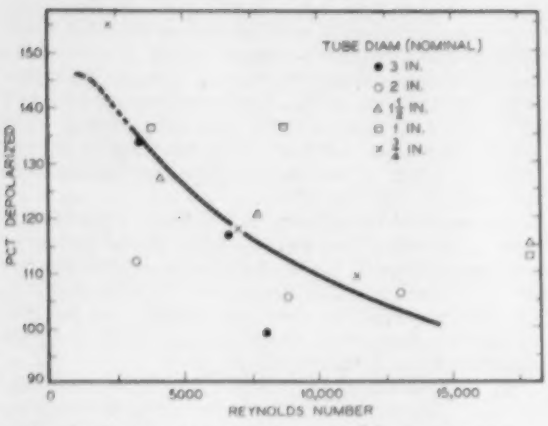

Fig. 5—Graph of data from test 31. Percent depolarized vs Reynolds number.

observed that hindered settling is more pronounced, that is, there is a heavy-media effect and the separation is influenced more by the specific gravity of the mineral grains than would be the case with good depolarizing.

Depolarizing of Cobber Concentrate Before Grinding: In making the design layout for the Pilotac plant, it became evident that the simplest design for closing the ball mill circuit with a rake classifier would be to install the depolarizing coils on the ball mill feed (rougher magnetic separator concentrate), rather than on the ball mill discharge (classifier feed). This proposal was considered seriously, as it would also obviate passing the circulating load through the depolarizing coils and thus require a smaller depolarizing installation. It was also postulated that grinding in the ball mill would improve depolarizing.

This scheme has been investigated in the laboratory, at the pilot plant, and at the Pilotac plant and in each case has been found to give poor depolarizing. Data from a test made at the Pilotac plant are summarized in Table VIII.

A number of experiments have been made in an attempt to explain this, but nothing has developed that can be supported on any firmer ground than mere speculation.

Application of Magnetic Theory to Depolarizing: Several interesting observations were made during the course of the investigation that differ from those made by previous investigators:

1) Heating above the Curie point and cooling, slow withdrawal of a pulp from an alternating field, and passage of a pulp in an enclosed container through an alternating field all give equally good depolarization.

2) Depolarization significantly better than obtained by the above methods can be obtained by passing a pulp through an alternating field in streamline flow.

3) Depolarization by flowing through an alternating field at very low Reynolds number is not as effective as at a moderate Reynolds number, and in fact, is very nearly that obtained by any of the methods enumerated under item 1 above.

It is doubtful that *perfect depolarization*, with reduction of the net moment of the particles to zero, has been effected in any of the tests, even when values of *Percent Depolarizing* as high as 180 to 200 pct have been achieved. Examination of well depolarized pulps under the microscope has revealed considerable flocculation, which it seems could only be due to residual external magnetism in the particles. Hartig and co-investigators (Ref. 2, p. 13) have proposed a method for estimating the behavior of a *perfectly depolarized* pulp. They studied the settling rate of a pulp depolarized by the slow withdrawal method in comparison to that of equally-sized pyrite, a nonferromagnetic material, of approximately the same specific gravity as magnetite. They found that the settling rate of the pyrite was considerably slower, indicating a significant amount of magnetic flocculation for the depolarized magnetite.

Considerable speculation could be carried on concerning the reasons why some preferential orientation of the domains remains after depolarizing, but as it is not supported by direct experimental evidence, it will not be attempted here. It can be pointed out that the only element common to depolarizing by Curie treatment and the other methods enumerated in item 1, above, is the quiescent condition of the material, which may have some bearing on the fact that equivalent depolarizing results are obtained.

In studying the behavior of magnetite particles under the microscope, Hartig (Ref. 2, pp. 6, 7) observed that in a 60-cycle field single particles rotated, presumably at a speed of 60 rps, in much the same fashion as the rotor in a synchronous electric motor. He further observed that if a group of particles were placed in a close proximity in an alternating field of gradually increasing intensity the particles would at first rotate and then tend to form into groups, or chains. After these chains formed the magnetic forces holding them together were strong enough to prevent rotation, although they usually continued to vibrate. With high coercive force magnetite, the tendency to form chains was much less pronounced, and the particles continued to rotate, even at high field strength.

Table VIII. Depolarization Tests on Cobber Concentrate and Ball Mill Discharge

Test No.	Pct Solids		Coil in Use		Pct Depolarized
	Ball Mill Discharge	Classifier Overflow	Ball Mill Feed	Ball Mill Discharge	
A	67.7	46.3	On	On	122*
B	67.7	39.8	On	On	131
C	67.7	39.8	On	Off	65
D	67.3	41.2	On	Off	66
E			On	Off	61
F			On	Off	70
G			On	On	114
H			On	On	126
I		46.0	On	On	122
J		43.2	On	Off	69
K	67.0	42.3	On	Off	63
L	67.0	41.2	On	Off	65

* In Test A a sample of the ball mill discharge taken before passing through the ball mill discharge depolarizing coil showed 65 pct depolarized.

This chaining of particles appears to be of considerable importance in depolarizing. Obviously if a particle follows the alternating field by rotating, there are no reversals of polarity of the domains and the particle will remain magnetized. Thus the chaining-up of particles appears necessary to prevent such rotation.

In high coercive force material the resistance to chaining precludes depolarization with a 60-cycle

field. Higher frequencies are required, so that the speed of rotation of the field exceeds the speed of rotation that can be attained by the particles.

With low coercive force material the particles have an opportunity to form chains as they pass through the high intensity portion of the field. If the pulp is in streamline flow, it appears that these chains persist through the declining portion of the field, thus preventing rotation of the particles. However, if flow is turbulent these chains are sheared apart, allowing rotation of the particles and in turn preventing effective depolarizing. In the case of free fall through the coil, it appears that even though the flow might be turbulent at the orifice discharge it turns into streamline flow during the free fall.

Although the chaining effect appears to offer a satisfactory explanation of why good depolarizing is not achieved in turbulent flow, it does not explain why streamline flow is better than depolarization in a quiescent condition or with very low velocity of flow. Apparently some relative motion of the particles is required, but it is difficult to explain why this is so.

Electrical Characteristics of Alternating Current Coils

During the course of these investigations it became necessary to construct a number of a-c coils of various sizes and shapes. Electrical characteristics were then ascertained, the field intensity being measured with the search coils described on p. 202. Various formulas found in handbooks and textbooks of electrical engineering were applied to these coils, and several were selected as capable of producing most accurately the electrical characteristics of any particular coil. In measuring field intensity it was assumed that the formula for the field strength of an *ideal* coil was sound.

Field Intensity: For the point of maximum intensity along the axis (H_{max}), the formula used to calculate the $H_{axis\ center}$ for the standard coils can also be used to calculate the intensity at the maximum point along the axis. The value of R in the equation is taken as the arithmetic average of the radius of the windings (in cm).

The field intensity for any point, P, along the axis can be calculated by the general form of the above equation, given by Atwood,[9] as

$$H_{axis}P = \frac{0.2\pi NI}{S}\left[\frac{\left(\frac{s}{2}-b\right)}{R^2+\left(\frac{s}{2}-b\right)^2}+\frac{\left(\frac{s}{2}+b\right)}{R^2+\left(\frac{s}{2}+b\right)^2}\right]$$

where b is the distance, in cm, of point P along the axis from the coil center. In the case of a tapered coil, the coil may be considered to be formed by a series of flat *pancakes* of decreasing winding thickness. The field intensity at any point may then be calculated by calculating the field for each of these pancakes and by simply adding the field intensity contributed by each pancake.

Inductive Reactance: The formula given by Pender and DelMar[10] for inductance was found to give excellent agreement between calculated and measured values of inductive impedance.

Heat Dissipation: Power is consumed in overcoming ohmic resistance and proximity and skin effect resistance. These losses are of the RI^2 type and appear in the form of heat. Ohmic resistance can be easily measured or calculated.

The terms *proximity* and *skin effect resistance* relate to nonreactive impedance effects that are peculiar to alternating current and are therefore not measured when ohmic resistance is measured. However, with alternating current, they can be treated as an ohmic resistance and result in power losses of the RI^2 type.

No method could be found in the literature for calculating this type of resistance, and therefore estimation must be approached empirically, requiring data on a coil similar in geometry to the coil being estimated.

Power, resistance, and current measurements can be made at various temperatures. From the power and current, total resistance can be calculated and the proximity and skin effect resistance determined by subtracting the ohmic resistance from the total resistance. Curves can then be plotted of the two types of resistance vs temperature. The ohmic resistance of the projected coil can then be calculated and the proximity and skin effect estimated from the curves.

The curves of Ref. 11 were found to be fairly reliable for calculating heat dissipation.

Summary and Conclusions

It has been shown that effective depolarization of pulps of low coercive force ferromagnetic material can be obtained by flowing the pulps through a 60-cycle alternating field under the following conditions: 1) when the pulp is in streamline flow; 2) when field strength of the coil is at least 300 oersteds (effective value); and 3) when the velocity of flow is such that the rate of decline of field intensity in any particle as it passes through the field does not exceed 50 pct per alternating cycle.

The most effective means for practicing depolarizing on a commercial scale was found to be the discharge of the pulp through orifices into the air core of an a-c solenoid so that the pulp passes through the coil in free fall.

A method of evaluating the effectiveness of depolarizing was developed.

Techniques for measuring field strength of alternating fields were developed, together with methods for calculating the electrical characteristics of alternating current coils.

Acknowledgments

The writers acknowledge with thanks the substantial contribution to the present investigation made by M. V. Mielke and by R. L. Bennett, J. E. Foricea, G. K. McMullin, and O. E. Palasvirta of the research staff, Oliver Iron Mining Div., U. S. Steel Corp. They appreciate the guidance of R. J. Morton, manager of research.

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Deformations in the Shells Of Rotary Cement Kilns

The rotary kiln is subjected to various mechanical stresses that distort its steel shell and refractory lining. Stiffening rings mounted on the shell keep the hot kiln circular in their vicinity.

by S. M. Brisbane

THE life of refractory linings in rotary cement kilns can be shortened by uneven or inadequate support of the kiln and its shell and by variations in the conditions of operation. Alteration of these factors may, according to their nature, bring about mechanical deterioration of the lining or promote chemical attack. Chemical attack has been described elsewhere.[1-4] The distortion of cement kilns has been discussed in a general manner by Rochow,[5] who indicates the amount of distortion which may occur in an unlined shell, and by Rosenblad,[6] who states that the deformations of the shell are greatest above the trunnions. The present article indicates the extent of the distortion of a kiln to an oval shape in certain selected positions and the deviation from a straight line of the kiln along its length between two supports.

The cement kiln is a long, hollow, rotating cylinder consisting of steel plates which may be either welded or riveted together. This shell is supported on tires, frequently 60 ft apart, which roll on trunnions. The large mass of the kiln causes distortion of its cross-section; it becomes slightly oval, i.e., diameters lengthen as they become horizontal and shorten as they become vertical. There is also a tendency for the shell to bow between supporting tires; this bowing may be upwards or downwards depending on the position of the weight forces and the supports. The extent of the deviations from the ideal kiln shape was investigated.

Observations described in this paper were made on the shell of the clinkering zone between the first and second tires of two of the kilns at the Geelong works of Australian Portland Cement Pty. Ltd. The kilns were both 400 ft long and 10 ft diam with a welded enlarged burning zone 11 ft 6 in. diam. The shell was fabricated from mild steel and in this section its thickness was 1 in. It was lined with 4½ in. of chemically bonded magnesite-chrome bricks which were jointed with mild steel plates. The kilns operate on a 4 pct slope and the speed may be varied between 0.75 and 1.68 rpm. The wet process is used; kilns are coal fired and are fitted with integral coolers. Temperatures within the kiln are difficult to determine with any accuracy because of the absence of black body conditions, but surface temperatures are probably in the range 1420° to 1470°C. Average shell temperatures at the two positions at which the deformation studies were made were 370°C and 355°C respectively.

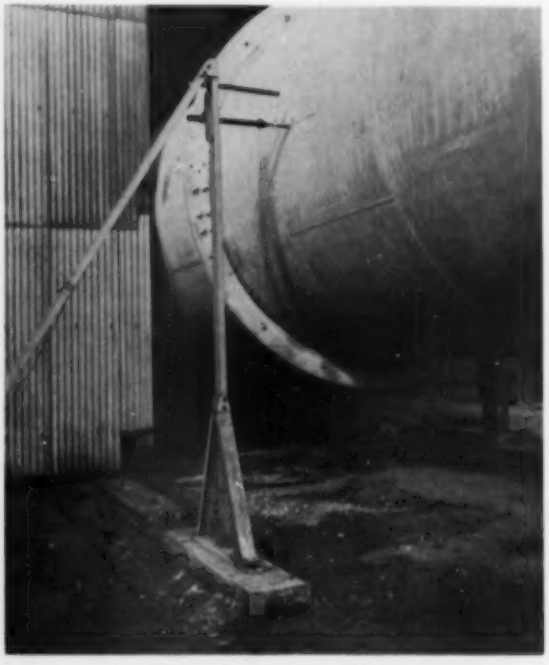

Fig. 1—Apparatus used for measuring horizontal diameters.

Methods: In determining the ellipticity it was necessary to measure the lengths of the vertical and horizontal diameters while the kiln was in operation; data obtained from a stationary kiln would not have the same practical significance. For this purpose the four points *V*, *W*, *X*, and *Y* at the ends of two mutually perpendicular diameters were marked on one kiln. The point *X* is shown in Fig. 1.

For the measurement of the length of the vertical diameter a vertical column, to which a horizontally aligned telescope was attached, was placed 10 ft from the kiln. The telescope could be racked up and down in a vertical plane. Two sets of readings were taken, one set when each of the points *V*, *W*, *X*, and *Y* was at its maximum height above the

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ground and the other set when each point was nearest the ground. The vertical distance corresponding to a particular diameter was read directly, but because the axis of the kiln was inclined to the horizontal, a correction had to be made to calculate the true diameter.

On each side of the kiln a device for measuring the horizontal diameter was erected. One of the two devices may be seen in Figs. 1 and 2. A plumb bob and measuring arm were attached to the structure. The measuring arm carried a fixed ruler and was hollowed out to receive a spring-loaded shaft upon which a pointer was mounted. The shaft made contact with the kiln by means of a small wheel; as the kiln rotated the pointer moved back and forth along the ruler.

Distance between the plumb lines of the two devices was measured directly and served as a datum. Distance between the plumb line and the kiln surface at any instant was calculated from ruler readings of the plumb line and the pointer, the fixed distance of the pointer from the kiln being known. Thus the length of the horizontal diameter could be calculated from readings taken as each of the four marked points passed the contact wheels on the side of the kiln.

Because of high air temperatures in the vicinity of the measuring devices the readings were made by means of a theodolite placed in an appropriate position about 15 ft from the measuring device. The shafts were in such a position that the point of contact of the wheels coincided with the point of contact of a vertical tangent to the kiln.

Measurements to determine the amount of bowing were made on the two kilns while they were stationary. This was necessary because the kilns oscillated in a vertical plane while they were rotating. It would be extremely difficult to obtain the number of simultaneous readings necessary to give an accurate picture of the outline of a kiln under these conditions.

A theodolite, placed under the lowest point of the kiln just past the second tire, was sighted along the line of the kiln towards the first tire. Vertical distance from this line to the lowest point of the kiln was read off on a ruler.

Results

Deformation of the Cross-Section: Measurements of the lengths of two mutually perpendicular diameters were made on one of the kilns over a period of several months. These readings were taken in the following positions between the first and second tires, which were approximately 58 ft apart: 1—14 ft from the first tire on the unmodified shell (points *V*, *W*, *X*, and *Y*); 2—at position 1 after a stiffening ring had been mounted 15 ft from the first tire; 3—7 ft 6 in. from the stiffening ring towards the second tire (points *A*, *B*, *C*, and *D*); and 4—at position 3 after a second stiffening ring had been mounted 30 ft from the first tire.

These positions were chosen to determine the influence of stiffening rings on the rigidity of cross-sections near them and at a position midway between two of them.

Differences in the length of a given diameter when horizontal and when vertical were taken as a measure of the deformation of the shell. In general little day to day fluctuation of the amount of deformation occurred; 1/16 in. was the maximum observed. Over a period of several weeks the amount of deformation fluctuated according to conditions within the kiln; the maximum observed change of deformation was ¼ in. These observations indicated that during a particular run of the kiln, increases and decreases of the amount of deformation occurred and the cross-sectional shape varied accordingly.

Table I. Cross-Sectional Deformation

Differences in Inches Between Length of Diameter When Horizontal and Vertical

Position on kiln diameter	1		2		3		4	
	VW	*XY*	*VW*	*XY*	*AB*	*CD*	*AB*	*CD*
Deformation, max.	16/32	20/32	2/32	2/32	13/32	12/32	12/32	10/32
Deformation, min.	12/32	12/32	nil	nil	8/32	8/32	8/32	7/32
Change of deformation	4/32	8/32	2/32	2/32	5/32	4/32	4/32	3/32

Eccentricity of Rotation

Horizontal Diameters of Paths Described by V, W, X and Y

Diameter Length, ft and in.	*VW*	*VW*	*XX*	*YY*	*VW*	*XY*
	11-8^{21}/32	11-8^{20}/32	11-9^{1}/32	11-9^{0}/32	11-8^{20}/32	11-8^{8}/32

The extent of the distortion of the kiln is shown in Table I where the maximum and minimum observed difference between the length of a marked diameter when horizontal and vertical are shown; the horizontal length was always the greater one.

The second section of Table I (Eccentricity of Rotation) has been compiled to show that the diameters of the paths described by the marked points *V*, *W*, *X*, and *Y* are not the same, indicating that the rotation of the kiln is eccentric. The horizontal diameters *VW*, *XY* measured at the same time are given for comparison.

Some of the unmarked points intermediate in position between *V*,*W*, etc. apparently suffered a greater eccentricity of movement. On the occasion that the figures in the section of Table I were recorded, the maximum movement of one of the pointers along

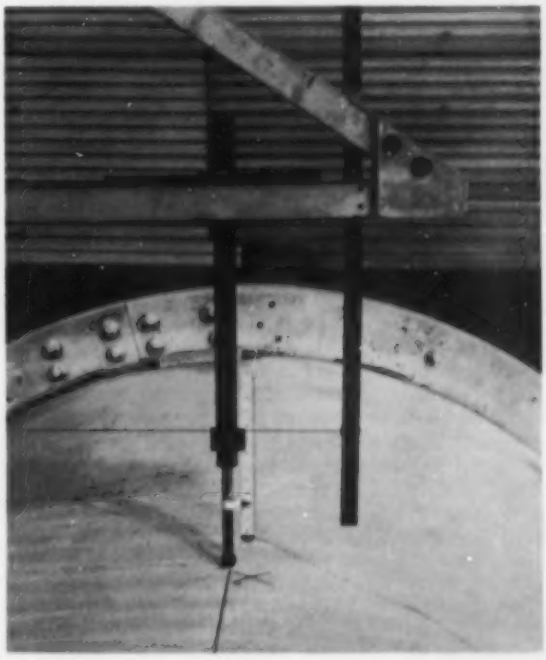

Fig. 2—Measuring arm and spring-loaded shaft.

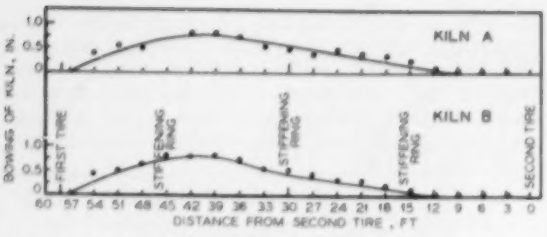

Fig. 3—Upward bowing of kilns between first and second tire.

the length of a ruler during one revolution was ⅞ in. Telescope readings indicated that a comparable movement occurred in the vertical direction. Further eccentricity of rotation was revealed on other occasions by a study of the distances through which the pointers on each side of the kiln moved. The maximum difference between these distances was observed to occur when the lateral displacement was 1¼ and 1 in. respectively. Another source of stressing of the lining was seen to occur during relining of a portion of the kiln. A jack placed in position near the measuring device was tightened to hold the bricks in place before the kiln was rotated slightly and the horizontal diameter was seen to increase by ¼ in.

Determination of Bowing: Measurements were taken every 3 ft on the two kilns while they were stationary. These kilns were fitted with integral coolers. Fig. 3 gives a picture of the shape of each kiln and indicates that there was an upward bowing of the kiln which reached a maximum of about ¾ in. approximately 18 ft past the first tire.

Discussion

The weight of the kiln and its contents is carried on a series of supporting rollers. Because of the presence of reaction forces here, the shape of the shell is probably more irregular in a cross-section near these supports than elsewhere, and it approaches more nearly to an elliptical shape as the distance from the rollers increases.

The figures presented in Table I, first section, indicate that in position 1 where the maximum distortion in these tests was met, the horizontal diameter was observed to be longer than the vertical by amounts ranging from ⅜ to ⅝ in. and that the kiln was held more closely to a truly circular shape while hot in the vicinity of the test marks after a stiffening ring had been mounted. As the life of the refractory lining is known to have increased after the installation of stiffening rings spaced 15 ft apart between the first and second tires, the influence of these rings apparently extended beyond the position at which readings 1 and 2 were taken. Readings taken at 3 and 4 indicated that while the maximum deformation had become smaller, possibly due to the presence of the first stiffening ring and the distance from a supporting roller, it was approximately the same after the installation of the second ring.

The operating staff believes that the fitting of the rings to each kiln has played a part in appreciably increasing the life of the refractory, which in one kiln now averages 140 days in the section where conditions are most severe, and a little less in the kiln on which this study was made.

Only small variations in the deformation were observed on consecutive days. This is to be expected, as the amount of change is attributed to differences in the temperature of the shell, thickness of clinker coating, formation of rings within the kiln, and variations of load. Changes in these variables would normally be slow and their influence felt over longer periods.

The sidewise displacement of the kiln as indicated by the movement of the pointers showed that the rotation of the kilns was slightly eccentric. From this, and from the tendency of the kiln to deviate from a circular cross-section, it would be expected that uneven stressing of the kiln and its supports would result and that this state would vary with the rotation of the kiln.

During each revolution of the kiln, the shell and the lining were subjected to an ever-changing stress which was shown by the lengthening and shortening of any diameter. The joints between the bricks when at the top and bottom of the cycle tend to open at their inner edges and open at their outer edges when at the ends of a horizontal diameter. The elastic deformation of the bricks is, in general, large enough to accommodate this type of stress, but continuous cyclic stressing is undoubtedly one of the factors leading to ultimate breakdown of the brick.

Bowing of the kiln is upward, not downward, between the first and second tires. This is due to the lever action of about 24 ft of the kiln weighing 120 tons, which overhangs the first tire and carries integral coolers. Because of its weight and the weight of its contents, it is probable that the kiln sags downward between supports further up the kiln.

Conclusions

The rotary kiln is subjected to various mechanical stresses that result in distortion of its steel shell and refractory lining. Tests carried out during operation of the kiln indicate that stiffening rings mounted on its shell keep the hot kiln circular in their vicinity and that the life of the refractory lining has been increased as a result. If the rings were placed at closer intervals, even better results might be achieved.

Elimination of the bowing of the kiln would also relieve some of the stress in the region where the life of the refractory is shortest. The maximum life possible for any particular lining could only be expected with a completely rigid kiln and constant operating conditions.

Acknowledgments

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The Circular Line Electrode In Equipotential Prospecting

by Lloyal O. Bacon

IN the spring of 1952 Calumet and Hecla Inc. began a geophysical program near Shullsburg, Wis., in the Wisconsin-Illinois lead-zinc district, to assist the geological and drilling exploration programs.

Sphalerite, the ore mineral in this area, occurs with a considerable amount of marcasite. In general the higher the percentage of sphalerite in the ore, the higher the percentage of marcasite; however, there may be mineralized zones high in marcasite but low in sphalerite. Orebodies in general are relatively narrow and elongated.

Reconnaissance exploration of virgin areas consisted of drilling along lines at 500 to 1000-ft intervals. Whenever a mineralized zone was intersected additional drilling was done to determine whether or not the zone carried zinc percentages of ore grade and, if so, to delineate the body.

Calumet and Hecla Inc. was interested particularly in a method that would show the direction and position in which to drill from the original discovery hole. This suggested a method of contacting the orebody, which occurs at depths ranging from 100 to 200 ft, with one electrode. After a number of procedures had been considered it was decided to use equipotential line methods.

Instrumentation and Field Procedure: The power source used was a 400-cycle Signal Corps motor-generator having a rated output of 1200 w at 115 v. The detection unit consisted of test probes, a two-stage amplifier, and head phones for determining the equipotential line by audio null.

Field procedure consisted of contacting the sulfide body in the hole by a specially built spring-loaded expanding electrode which would be lowered into the hole, in the closed position, until it reached the mineralized zone. At that point the mechanism was released so that the arms would make contact with the walls of the hole in the same manner that a well-bore caliper does. This electrode was then connected to the generator, the other terminal of which was connected to the surface electrode. The surface electrode was either a point, a straight line, or a circular line electrode.

The point surface electrode was placed at a considerable distance from the hole, that is, 2500 to 5000 ft, depending somewhat upon the depth to the sulfide zone and the distance from the hole containing the subsurface electrode to which exploration was considered. A higher voltage output from the power source would have been desirable, although no difficulty was encountered in determining null points to a distance of 500 ft.

Straight line electrodes used were approximately 1000 ft in length at a distance of approximately 1000 ft from the hole containing the subsurface electrode.

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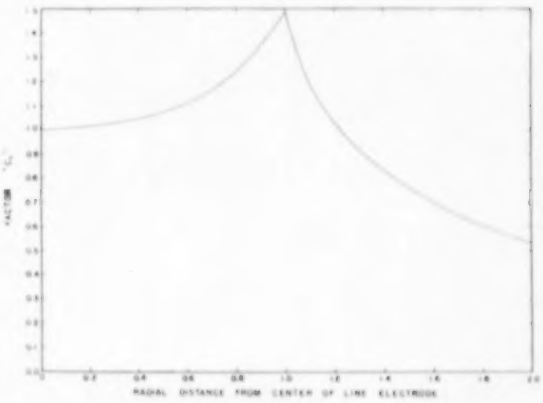

Fig. 1—Variation of factor C_r with distance from center of line electrode.

The circular line electrode used consisted of 4400 ft of bare No. 10 copper wire, which provided a circle of 700-ft radius. All line electrodes were fastened to the ground at 20-ft intervals with copper staples 4 in. long. Equipotential points were determined at 25 to 100-ft intervals. Location of the points was made by plane table and stadia. In open country with a three-man crew, the points were plotted as they were determined. With a two-man crew, pegs were placed at equal potential points and surveyed in after several equipotential lines were determined.

Although interpretation of results given in this paper is qualitative, the paper as a whole would not be complete without a discussion of the theoretical distribution of potential due to a circular line electrode. The theoretical distribution would be required if a quantitative interpretation of the measured potential distribution were to be made.

The theoretical potential distribution due to a circular line electrode can be obtained by means of Legendre polynomials. Using the method as developed by Weber,[1] the potential for a circular line electrode in a semi-infinite, homogeneous, isotropic medium can be expressed, using the spherical coordinate system, as:

$$V_{(r,\alpha)} = \frac{\rho I}{2\pi R}\left[\sum_{n=0}^{n=\infty}\left(\frac{r}{R}\right)^{n} P_n(\cos\theta)\, P_n(\cos\alpha)\right] r<R \quad [1]$$

or

$$V_{(r,\alpha)} = \frac{\rho I}{2\pi R}\left[\sum_{n=0}^{n=\infty}\left(\frac{R}{r}\right)^{n+1} P_n(\cos\theta)\, P_n(\cos\alpha)\right] r>R \quad [2]$$

where:

θ is the angle at the origin, taken on the axis of the circular electrode between the axis and the line drawn to the circumference of the circular electrode.

α is the angle between the axis and the radius, r.

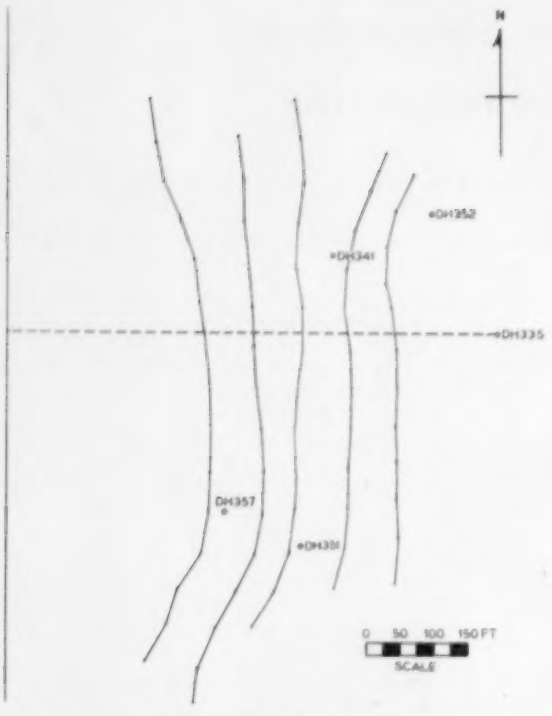

Fig. 2—Equipotential survey, Hendrickson orebody, southwest Wisconsin. Point electrode: location DH 335, depth 160 ft. Line electrode: location 690 ft from DH 335, length 1000 ft.

r is the radius from origin to point in question.
R is radius of circular electrode.
ρ is resistivity of the semi-infinite medium.
P_n is Legendre polynomial of the first kind.
V is the potential.
I is the current.

If the origin is taken at the center of the circular electrode, θ becomes $\pi/2$; and since only the evaluation of the integral in the plane of the circular electrode is of interest here, α is also $\pi/2$. Eqs. 1 and 2 reduce to:

$$V_{(r)} = \frac{\rho I}{2\pi R}\left[\sum_{n=0}^{n=\infty}\left(\frac{r}{R}\right)^n \{P_n(\cos \pi/2)\}^2\right] \quad r<R \qquad [3]$$

and

$$V_{(r)} = \frac{\rho I}{2\pi R}\left[\sum_{n=0}^{n=\infty}\left(\frac{R}{r}\right)^{n+1} \{P_n(\cos \pi/2)\}^2\right] \quad r>R \cdot \qquad [4]$$

The potential at a point due to a circular electrode in a semi-infinite, homogeneous, isotropic medium can thus be expressed as:

$$V_{(r)} = \frac{\rho I}{2\pi R} C_r$$

where C_r is a factor dependent upon the radial distance, r, from the center of the circular electrode of radius R.

Fig. 1 shows the variation of the factor C_r with radial distance from the center of the circular electrode. The factor varies from 1 at the center of the circular electrode to about 1.5 at the radius of the circular electrode, thence dropping very rapidly outside the circular electrode, approaching zero asymptotically.

The potential at the surface for a point electrode at a depth z in an infinite, homogeneous, isotropic medium is:

$$V_{(z,r)} = \frac{\rho I}{2\pi} \frac{1}{\sqrt{z^2 + r^2}}$$

where:
ρ is resistivity of the medium.
I is the current.
z is depth of electrode below the surface.
r is radial distance to the point in question on the surface.

The potential at any two points, P_1 and P_2, on the surface due to both the circular line electrode and the subsurface electrode is given by:

$$V_{P_1} = \frac{\rho I}{2\pi}\left[\frac{C_{r_1}}{R} - \frac{1}{\sqrt{z^2 + r_1^2}}\right]$$

$$V_{P_2} = \frac{\rho I}{2\pi}\left[\frac{C_{r_2}}{R} - \frac{1}{\sqrt{z^2 + r_2^2}}\right]$$

Thus the potential difference between two points, P_1 and P_2, on the surface due to the subsurface point electrode and the surface line electrode is:

$$V = V_{P_1} - V_{P_2} = \frac{\rho I}{2\pi}\left[\frac{C_{r_1} - C_{r_2}}{R} - \frac{1}{\sqrt{z^2 + r_1^2}} + \frac{1}{\sqrt{z^2 + r_2^2}}\right]$$

and the resistivity

$$\rho = 2\pi \frac{V}{I}\left[\frac{C_{r_1} - C_{r_2}}{R} - \frac{1}{\sqrt{z^2 + r_1^2}} + \frac{1}{\sqrt{z^2 + r_2^2}}\right]^{-1}$$

The potential lines would be circles both inside and outside the circular electrode, and the theory predicts that measurements can be made up to the radius of the electrode. Measurements very near the line electrode are not practical, since the circular electrode does not make uniform contact with the surface along its entire circumference; instead contact is made at intervals along the circumference. It is believed that 0.9 radial distance is about the limit for practical use.

Results of the Geophysical Survey

In general the results obtained from the use of a point surface electrode in conjunction with the subsurface electrode were inconclusive, as no interpretable results were obtained on the one area in which the method was used.

Results obtained with the straight line surface electrode were difficult to interpret. Representative samples of the results obtained at the Hendrickson orebody are shown in Figs. 2 and 3. In Fig. 2 the line electrode lies in a north-south direction to the west of the known orebody. The equipotential lines, especially the two lines farthest west, indicate the presence of a conductive zone, which is the orebody, but give little indication of any extensions or variations from the main conductive zone. Fig. 3 shows the results obtained when the line electrode was oriented in a nearly east-west direction to the north of the known orebody. Little variation of the equipotential lines occurs, although there is some variation to the north of drillhole 346. Interpretation of Figs. 2 and 3 would have been simplified if the equipotential lines had been extended and if the theoretical distribution of equipotential lines, for homogeneous ground and the electrode configuration used, were superimposed on them.

Results of the circular line electrode at the Hendrickson orebody are shown in Figs. 4 and 5. Fig. 4 shows the equipotential results for the case in which

the circular line electrode is not concentric with the hole that contains the subsurface electrode. In this case the line electrode is concentric with drillhole 352, but the subsurface electrode is in drillhole 335 about 200 ft to the southeast. The theoretical equipotential lines would not be concentric circles in this situation. Results indicate a fairly large conductive zone in the northeast portion of the area as well as a smaller and narrower conductive zone nearly due west of the center of the area. Fig. 5 shows the results obtained when the subsurface electrode was put in drillhole 352 at the center of the circular line electrode. The anomalous areas are more clearly indicated in this figure and are easier to interpret, since the theoretical equipotential lines would be concentric circles. On the basis of this work two drillholes were recommended, one in the northeast portion of the area and the other in the west central portion of the area. These locations are shown in Fig. 5 as drillholes, *DH*. The hole in the northeast portion of the area was drilled and encountered a zone of marcasite containing sufficient zinc to be of ore grade. Additional drilling added a considerable tonnage of ore to the known reserves of this mine.

Results of the use of the circular line electrode in the Northwest Linden area are shown in Fig. 6. The ore zone here was at a depth of about 100 ft. The conductive zone is readily interpretable. An indication of the narrowness of the conductive zone is the fact that the sulfide contact passes between drillholes DH20 and DH21.

There are certain limitations as well as advantages in using the circular line electrode, and although quantitative interpretative methods were not applied, it should not be too difficult a procedure.

Limitations of the Circular Line Electrode: If the country is wooded, the time required to lay out the circular line electrode and map equipotential lines becomes excessive. There are also limitations common to other equipotential methods:

1) Little variation in equipotential lines is obtained at radii less than the order of depth of the subsurface electrode. This is due to the fact that a horizontal conductive body would have little effect on the potential distribution at the surface directly above the electrode.

2) Equipotential lines are distorted in the vicinity of the circular line electrode owing to geometry of the earth-electrode contacts.

3) The equipotential null point is difficult if not impossible to obtain when a highly conductive surface layer such as shale exists.

Fig. 3—Equipotential survey, Hendrickson orebody. Point electrode: location DH 351, depth 140 ft. Line electrode: location 1200 ft from DH 351, length 1200 ft.

Advantages of the Circular Line Electrode: Among the advantages of the circular line electrode given below the first is of particular importance:

1) For homogeneous ground equipotential lines would be circles; thus any deviation from a circle is an indication of nonhomogeneity. This results in ease of interpretation.

2) Quantitative information can be obtained by measuring the actual difference of potential between equipotential lines, calculating the theoretical distribution of the potential at the surface of the ground, and then subtracting the theoretical potential from the observed potential. Resistivity values can also be calculated for the case of homogeneous ground.

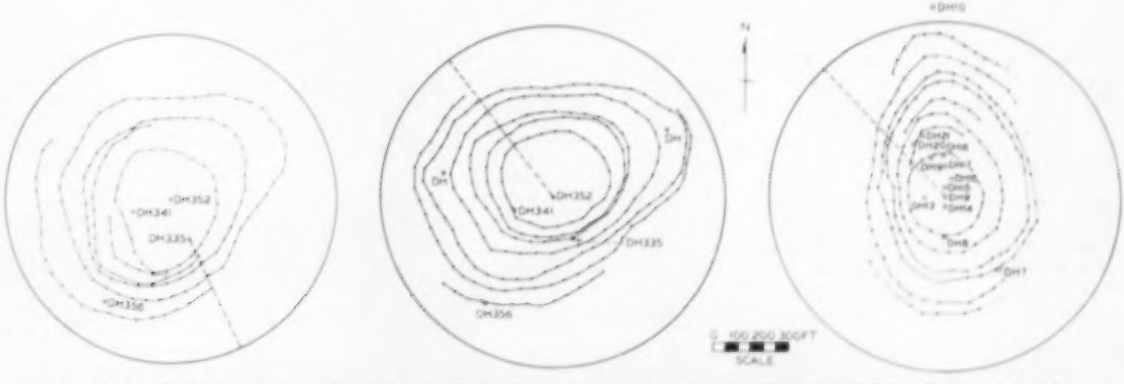

Fig. 4 (left)—Equipotential survey, Hendrickson orebody. Point electrode: location DH 335, depth 165 ft. Circular electrode: center DH 352, radius 700 ft. Fig. 5 (center)—Equipotential survey, Hendrickson orebody. Point electrode: location DH 352, depth 165 ft. Circular electrode: center DH 352, radius 700 ft. Fig. 6 (right)—Equipotential survey, Northwest Linden area, southwest Wisconsin. Point electrode: location DH 9, depth 105 ft. Circular electrode: center DH 9, radius 700 ft.

3) A check on the accuracy of equipotential determinations can readily be made by returning to the starting point.

Acknowledgments

The writer expresses thanks to Calumet and Hecla Inc. for permission to use the data for this paper as well as for permission to publish. He also thanks T. M. Broderick of Calumet and Hecla Inc. for suggestions concerning the writing of this paper.

References

[1] E. Weber: Electromagnetic Fields, vol. 1, pp. 489-90. John Wiley & Sons Inc., New York, 1950.

Discussion

The Circular Line Electrode in Equipotential Prospecting

by Robert G. Van Nostrand

In view of the apparent success which Professor Bacon has reported in using circular electrodes to detect the trend of sulphide ores, I would like to bring attention to an additional technique that should be compared critically with his. The work, upon which this report is based, was done in 1948 by F. C. Farnham and by me for the U. S. Geological Survey in close cooperation with Calumet and Hecla in the section of Wisconsin where Professor Bacon's work was done. Details of the method and the results have previously been published in 1949 as part of my Master's thesis at the Missouri School of Mines.

The technique we used was to place one current electrode at the top of the core hole and the second current electrode at various depths in the hole. The range of depths included the pay zone. Potential electrodes were then placed at a distance from the hole equal to about 1.5 times the depth of the ore, in each of the eight cardinal directions. In the present case, the depth of the ore was between 250 and 300 ft, so the potential electrode distance was chosen to be 400 ft. A ninth potential electrode was placed 1500 ft from the hole in some random direction. For a fixed position of the down hole current electrode, a current was passed through the current electrodes and the potential was measured at each of the eight potential electrodes with respect to the ninth electrode, on the assumption that the potential of the latter electrode remained constant throughout the experiment. The down hole electrode was then moved to a different position and the experiment was repeated.

It was expected that as the down hole electrode was drawn up through the mineralized zone the changes in potential at points in the direction of the trend of the mineralized zone would be less than the changes in potential at other points. Four drillholes were used in these preliminary experiments, three in which there was extensive mineralization including ore and one in which practically no mineralization was found. In the nonmineralized hole there was no observable effect. In the first mineralized hole there was a very pronounced effect which led to the successful prediction that the ore trend, which was being followed cross-country by a line of holes, terminated near that hole. The second and third mineralized holes were adjacent holes in a single line that cut across the mineralized zone. Although the effect was not so evident in these holes, it was strong enough to justify predictions at to the trend of the ore. This drilling project, which was being carried on by Vinegar Hill Zinc Co., was not completed while we were still there and our predictions were never verified nor refuted.

I would like to point out that theory indicates that the potential should be lower in the directions in which the ore trends. However, our experiments showed that near surface effects, such as marshy ground, completely masked any reduction in potential which may have been associated with the ore. The technique described herein was devised to circumvent the undesirable effects of near surface inhomogeneities.

If in comparative tests it can be shown that the above technique has the same resolving capacity as the preferred technique of Professor Bacon, it is obvious that it offers the advantage of simplicity and ease of application. It is considerably easier to lay out eight radial lines from the hole than to survey the line for the circular electrode required in Professor Bacon's method. Moreover, it should be noted that we did not find any necessity for using special current electrodes in the hole; a steel stake hung at the end of an insulated cable was sufficient. The potential electrodes consisted of nonpolarizing porous pots. A direct current was used and measurements were made with potentiometers.

L. O. Bacon *(author's reply)*—My first approach to the exploration problem in southwest Wisconsin was to use a subsurface current electrode with the surface current electrode attached to the casing of the hole. Since the casing was short, it effectively was similar to Mr. Van Nostrand's current electrode at the top of the core hole. Equipotential lines were investigated out to a radius of approximately 400 ft from the bore hole. This is effectively the same configuration Mr. Van Nostrand used except that we maintained the subsurface electrode at a constant position and did not determine the change in potential with change in position of the subsurface electrode. Our results using the above technique were not very good. One indication of a conductive zone was interpreted from the data but did not coincide with the known zone of mineralization, nor did the data indicate this zone. Unfortunately we did not obtain data using the circular line electrode at that particular location, so no direct comparison is available.

I am slightly perturbed by Mr. Van Nostrand's statement that with his technique the effect obtained in the first mineralized hole led to the successful prediction that the ore trend terminated near that hole—in view of the last sentence in the same paragraph which states, "This drilling project . . . was not completed while we were still there and our predictions were never verified nor refuted."

We did not find it necessary to use a special current electrode, but merely devised one that would be adequate before beginning work, thus eliminating the necessity of determining this factor. I also pointed out in my paper that under certain conditions the circular line electrode was extremely time-consuming; however, with its use much more data is obtained, and this extra information is often the key to the problem. Whether or not one method is superior to the other remains to be proved. In conclusion, I concur that theory indicates that the potential is lower in the direction that ore trends and that this is true in practice is shown by Mr. Van Nostrand's work and mine.

aime news

Arizona Section Holds Annual Meeting

The Arizona Section held its annual meeting on Dec. 5, 1955 in Tucson. Nearly 750 members and their wives took part in the one-day meeting, the largest yet sponsored by the Section. Members came from Arizona, New Mexico, California, Utah, Colorado, Texas, and Mexico.

Sessions were held at the Pioneer Hotel with registration beginning at 8:00 am. Three technical sessions on mining geology, underground mining, and smelting were held in the morning. In the afternoon two sessions dealt with open pit mining and ore dressing.

Speaker at the dinner was Carl E. Reistle, Jr., President-elect of the AIME, and vice president, Humble Oil & Refining Co. He spoke on "Off-Shore Developments in the Oil Industry." Mr. Reistle described the difficulties as being legal, economic, and technical. Earlier in the day Mr. Reistle addressed mining and engineering students at the University of Arizona. Among other things, he discussed what management looks for in young engineers.

Technical Program

Underground Mining

Chairman of the Underground Mining meeting was E. R. Tomkinson, of Shattuck Denn Mining Corp. B. Van Voorhis, chief engineer, Magma Copper Co., presented "Stoping at Magma." E. G. Williams, mine superintendent, Miami Copper Co., discussed "Conveyor Belt Haulage at Miami Copper." Louis Bombardieri, chief engineer, Iron King mine, spoke on "Mining Methods at Iron King."

Mining Geology

E. F. Reed was Chairman of the mining geology session. Mr. Reed is with The Anaconda Co. Harrison A. Schmitt, consulting geologist, Silver City, N. M., delivered a paper on "The Silver Creek Mine, Mogollon District, New Mexico." W. E. Heinrichs, Jr., manager, Minerals Exploration Co., reported on "The Status of Mining Geophysics Today."

Smelting

The smelting session was attended by 54. M. G. Fowler of Phelps Dodge Corp. was Chairman. J. W. Byrkit, smelter superintendent, Phelps Dodge Corp., presented "The Ajo Holding and Oxidizing Furnace." Officers of the Arizona Section's Smelting Div. for the coming year are: F. J. Downey, Chairman, and W. R. Kelly, Secretary. Both men are with American Smelting & Refining Co.

Open Pit

The open pit session was attended by 118. J. H. Gray of Copper Cities Mining Co. was Chairman. H. Furman Byars, superintendent, Isbell Construction Co., discussed rear dump trailer units. J. E. Petersen, director of industrial and labor relations, Ray Mines Div., Kennecott Copper Co., posed the question, "What Does Top Management Expect From Its Operating Staff in the Field of Labor Relations?" The Section's Open Pit Div. elected D. R. Purvis, Chairman. Mr. Purvis, mine superintendent, American Smelting & Refining Co., Silver Bell Div., will select a secretary later.

Ore Dressing

H. R. Hendricks of American Smelting & Refining Co. was Chairman of the ore dressing session. There were 80 at this meeting. Tailing disposal was the topic. R. Salter of American Smelting & Refining Co. discussed the Silver Bell concentrator; T. D. Henderson of Miami Copper Co., the Copper Cities concentrator; and H. K. Martin of Phelps Dodge Corp., the Bisbee concentrator. Mr. Martin was elected 1956 Chairman of this division of the Arizona Section. Spring meeting of this division will be held in Silver Bell, Ariz., probably early in April.

Evening Program

Following the cocktail party and dinner program, there was dancing until midnight. Guests included: AIME President-elect Carl E. Reistle, Jr., and Mrs. Reistle; AIME Director Charles R. Kuzell and Mrs. Kuzell;

(Continued on page 224)

Shown above are Archie Bowman, left, Montana Section Program Chairman; Cliff Hicks, Section Secretary, Bob Lynn, Chief Geologist, New Mexico Div., The Anaconda Co., Cliff Milkwick, Section Chairman, and Ed Shea, the Section's Program Adviser. They were among those responsible for the success of the Montana Section and the Last Chance Gulch Mining Assn. joint meeting in October 1955. Following a USBM film on uranium, Mr. Lynn spoke on field prospecting for uranium.

AIME Annual Meeting Program, Feb. 18 to 23, 1956

New Yorker and Statler Hotels, New York

Names of Divisions and Subdivisions are coded as follows: MIED—Mineral Industry Education Div. MED—Mineral Economics Div. M—Mining Subdiv. G—Geology Subdiv. Geophys.—Geophysics Subdiv. IndM—Industrial Minerals Div. Coal—Coal Div. MBD—Minerals Beneficiation Div. EMD—Extractive Metallurgy Div. IMD—Institute of Metals Div. ISD—Iron & Steel Div. Petroleum Branch—Named as such. SEG—Society of Economic Geologists.

SATURDAY, FEBRUARY 18

10 am
Council of Section Delegates
5:30 pm
National Membership Steering Committee

SUNDAY, FEBRUARY 19

9:30 am
National Membership Committee
11:00 am
Inter-Branch Council
12:30 pm
National Membership Committee Luncheon
2:00 pm
Registration
Board of Directors
MIED—Future of Engineering Education
4:30 pm
IMD Program Committee
5:00 pm
MIED Fellowship Hour and Buffet Supper
6:00 pm
SEG Council
7:30 pm
MIED, IMD—Future of Engineering Education

MONDAY, FEBRUARY 20

8:00 am
Registration
8:45 am
Meeting of presiding officers and authors
9:30 am
IndM—Dimension Stone and Slate
Petroleum Branch Executive Committee
M—Uranium
MIED—Training Engineers for Management
Coal—Mining Methods and Problems
EMD—Refractories
10:00 am
MBD—Business Meeting
12:15 pm
Welcoming Luncheon
2:00 pm
IndM—Dimension Stone and Slate
Coal—Continuous Mining Progress
2:30 pm
G, SEG—Ore Deposits
Petroleum Branch—1955 Oil and Gas Developments
M—Canadian Session
MBD—Concentration
MBD—Material Handling; Operating Control
IndM—Industrial Water
EMD, ISD—Slags, Mattes, and Fused Salts
EMD—Zinc Smelting
4:00 pm
Coal Div. Executive Committee
MGG Executive Committee
6:00 pm
Cocktail Party
8:00 pm
Dinner-Smoker

TUESDAY, FEBRUARY 21

7:30 am
EMD Executive Committee Breakfast Meeting
8:00 am
MBD Scotch Breakfast
8:15 am
Meeting of presiding officers and authors
9:00 am
MED—Business Outlook; Trends
IndM—Cement Aggregate Reaction
Geophys—Annual Review—Airborne Techniques
Petroleum Branch—Technical Session
M—Latin American Session
G, SEG—Deposits of Rare Metal Sources
Coal—Planning a Coal Preparation Plant
EMD—Lead, Zinc, Cadmium
EMD—Physical Chemistry of Roasting
9:30 am
MBD—Concentration
MBD, IndM—Air Separation of Nonmetallic Ores
10:00 am
Mining Branch Council
11:00 am
Howe Memorial Lecture
12:15 pm
MGGD Luncheon
Coal Div. Luncheon
2:00 pm
MIED Business Meeting
Petroleum Branch—Technical Session
G, SEG—Crystallization; Related Ore Deposits
MED—Strategic Minerals Session
MBD—Hydrometallurgy—Solution and Precipitation
MBD—Mill Design
Coal—Planning a Coal Preparation Plant
EMD—Lead Smelting
EMD—Fused Salt Systems
3:00 pm
Executive Committee, IndM
M—Symposium, Unwatering the Osceola Lode
4:00 pm
Annual Institute Business Meeting
4:45 pm
Special Institute Business Meeting
5:00 pm
Directors' Meeting, Executive
6:00 pm
Metals, Mining, and Petroleum Branch Social Hours
7:00 pm
Metals, Mining, and Petroleum Branch Dinners
9:00 pm
Informal Dance

WEDNESDAY, FEBRUARY 22

8:15 am
Meeting of presiding officers and authors
9:00 am
MED—Canadian-U. S. Economic Trends
M—General Mining Session
IndM—Chemical Raw Materials
Petroleum Branch—Technical Session
G, SEG—Nature of Ore Solutions
MBD—Concentration
MBD—Crushing and Grinding
Geophys—Case History, Instrument Development, Research
Coal—Symposium: Materials Handling
EMD—Symposium on Titanium
EMD—Pyrometallurgy
Woman's Auxiliary Annual Meeting
10:45 am
IMD Annual Business Meeting
12:15 pm
MED Luncheon
Mining and Metallurgical Society of America Luncheon
IndM Luncheon
EMD Luncheon
IMD Titanium Committee Luncheon
2:00 pm
M—General Mining Session
G, IndM, SEG—Geology of Nonmetallic Mineral Deposits
MBD—Starting a New Mill
Geophys—Geophysical Studies; Radioactivity
Coal—Utilization; Carbonization
MED—General Session
EMD—Extractive Metallurgy of Uranium
EMD—Copper Converting and Refining
Woman's Auxiliary Annual Meeting
3:00 pm
Committee on Physical Chemistry of Extractive Metallurgy
AIME Nominating Committee
7:00 pm
Annual Banquet and President's Reception

THURSDAY, FEBRUARY 23

8:15 am
Meeting of presiding officers and authors
9:00 am
G, SEG—Ore Deposits
IndM—General Session
MBD—Solids-Fluids, Separation, Pyrolysis
MBD—Crushing and Grinding
M—General Session
Coal—Utilization; Gasification
EMD—New Methods in Hydrometallurgy
EMD—Fused Salt Electrolysis
Geophys—Geochemistry
12:15 pm
MBD Luncheon
Bessemer Centennial Luncheon
2:00 pm
IndM—Mineral Synthesis
MBD—Richards Award
Coal—General Technical Session
EMD—Physical Chemistry of Hydrometallurgy
3:00 pm
MBD—Cleanup Session

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AIME Elects 1956 President From Petroleum Branch

THE sixth President of the Institute to represent the petroleum membership is Carl E. Reistle, Jr., of Houston. A vice president and member of the board of directors of the Humble Oil & Refining Co., in charge of the production dept., he is a respected executive in the oil industry and a man of distinctive personal and professional achievements.

Born in Denver in 1901, he later moved with his parents to Oklahoma City. He became intrigued with chemistry through his father's photoengraving business, but the romance of the booming oil industry in Oklahoma held an irresistible attraction for him. Deciding to combine the two, he entered the University of Oklahoma in 1918 to study chemical engineering, and worked as a roustabout during summer vacations. Upon graduation in 1922, Reistle joined the Petroleum Div. of the U. S. Bureau of Mines and was soon sent to the Salt Creek Field in Wyoming to develop an easy way to determine the gravity of oil. This work brought his assignment to the Laramie Station of the USBM when it was established in 1924. He was keenly interested in a number of factors concerned with the production of oil, and later that year he and D. B. Dow conducted some of the first experiments on the solubility of gas in oil. A paper on the work published in *Mining & Metallurgy* interested the late Henry L. Doherty, pioneer in this field, and was a forerunner to work that followed on the problem.

With 1931 came the discovery of the great East Texas oil field, the nation's largest. The drilling of thousands of wells there, overproduction, and 10¢ oil brought chaos from which order had to be restored. By then Reistle's ability had become evident to the U. S. Bureau of Mines, and he was assigned to work on this job in 1932. He began by attempting to measure reservoir pressures in the field and organize them on a systematic basis. When the East Texas Engineering Assn. was formed by operators in the field in 1933 to further this work, Reistle was invited to become its first field chairman. The cooperative effort that followed, in which he played a leading part, led to the launching of a water injection program in the field in 1942. The end product will be a tremendous increase in the recovery of oil from this field.

The Humble Co. was one of the largest operators in the East Texas Field, and upon observing his work there, the company invited him to become engineer-in-charge of its Petroleum Engineering Div. in 1936. His subsequent rise in the company attests to his ability: to head of the Petroleum Engineering Div. in 1940, to manager of production in 1945, to director in 1948, and to vice president in 1955. His present responsibilities cover the wide range of activities involved in directing the production operations for the nation's largest domestic oil producing company.

Warm personality traits have made friends for him everywhere he has gone. His good humor and fun-loving nature are revealed in a story Mrs. Reistle tells about when she accompanied him as a young bride to Laramie in 1924. As it was her first trip west, snow fences were new to her, and curiosity getting the upper hand, she asked Carl why such fences were built. He blandly told her that because the country was so flat the cows didn't have much exercise and the fences were put up for the cows to get exercise in jumping over them. She doubtfully accepted this and had to find out the truth later for herself.

Carl Reistle has been active in AIME and professional work during his entire career. He attended his first AIME meeting in 1924, presented his first paper before the Petroleum Div. in 1927, and has since been one of the strongest advocates of the Institute. He is noted for clearing the way for engineers in his company to participate in AIME, and one of the largest contingents at the Petroleum Branch Fall Meeting each year is the Humble Co. group. Through 15 published technical papers and a variety of articles and speeches, he has been a continuing contributor to engineering literature. His creative mind has produced technical tools and processes for which he now holds seven patents.

Our friend is an avid hunter and fisherman. His eagerness here, combined with his personal habit of being early for appointments, got him into some difficulty recently when he and a companion went to the mouth of the Mississippi off Louisiana for the opening of the duck season. They shared double-decker bunks in a lodge, with Carl in the top one, and agreed to arise at 3:00 am. Upon awakening during the night, Carl read his watch to be this uncomfortable hour. He bounded off the top deck, shook his companion, and went into the bath. After hurrying through a quick shave, he went back to arouse the companion in the lower bunk. This person looked at his own watch and discovered the hour to be 12:30 am—Carl had mistaken the hands of his watch at 12:15 to read 3:00 am. Under a barrage of invective, our anxious nimrod climbed back into the top bunk to caress his fresh shave and sleep out the remaining hours.

Carl Reistle characterizes the modern corporate executive: intellectual acumen, calm temperament, sound judgment, and the ability to assimilate the complexity of big business. Yet, a corporation is more than assets and balance sheets to him—it is people. He is genuinely concerned with the welfare of the people all up and down the line in a company, and is intensely loyal to those who work for and with him. Blessed with a happy family of four children, he has a keen interest in young people, and has served as president of the Houston Branch of Junior Achievement. He is now on the national board of directors of that organization.

His concept of AIME is that it is the professional society for engineering in all of the mineral industries, and he believes that all engineers in these industries have common ties. He feels that members of the Board of Directors must be concerned with the welfare of all Branches and Divisions of the Institute. He believes that the Institute has a great opportunity for the future, which will be realized by all members and groups working together for common goals. His own contribution, as President in 1956, will form a distinct page in the continuing record of the Institute.—*Joe B. Alford*

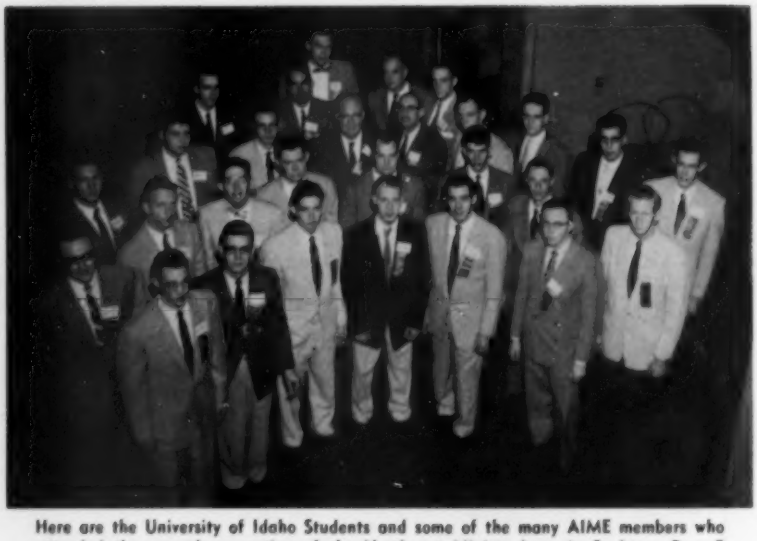
CARL E. REISTLE, JR.

PRESIDENT OF AIME IN 1956

Around the Sections

• More than 150 attended the **San Francisco Section's** annual reminiscence meeting on Dec. 14, 1955 at the Engineers' Club. Cocktails were sipped to music and dinner was followed by a floor show. Entertainment Chairman Fred Lohse and his Committee assembled a top-notch group of entertainers. On January 11 the Section met for a technical session. Lawrence B. Wright, chief geologist in charge of exploration for Southern Pacific Co., spoke on his company's exploration program.

• The **Ajo, Ariz., Subsection** met with the Woman's Auxiliary Dec. 8, 1955 for a social meeting. The WAAIME provided a bountiful potluck supper, after which a piñata party was held. Then a large group adjourned to the Copper Coffee Shop for dancing. Northern Sections wondering what piñatas are may remember seeing in Mexican markets these large pots or balloons filled with favors. Business at the November meeting included the adoption of a completely revised Subsection constitution and bylaws. Raleigh Sanderson of the U. S. Bureau of Reclamation at Wellton, Ariz., was the program speaker. The following officers were elected at the October meeting: Donald R. Cratty, Chairman; William C. Hunter, Vice Chairman; Forrest R. Rickard, Secretary-Treasurer.



Here are the University of Idaho Students and some of the many AIME members who attended the annual convention of the Northwest Mining Assn. in Spokane, Dec. 2 and 3, 1955. Other students came from State College of Washington, Montana School of Mines and the University of Alberta. See below.

• The **Florida Section** met the evening of January 9 at the Glass Diner, Lakeland, Florida. A symposium was held on the utilization of large draglines in phosphate rock mining.

• The **Columbia Section** took an active part in the 61st annual convention of the Northwest Mining Assn. held at Spokane, Dec. 2 and 3, 1955. Many of the 644 who registered for the meeting were AIME Members and the AIME was also well represented among the speakers.

Chairman of the AIME Session held on December 3 was F. R. Moral, chief, X-ray section, research dept., Kaiser Aluminum & Chemical Corp. The purpose of this session was to give mining people an idea of what physical metallurgy is. This was well done by S. A. Duran, assistant professor, physical metallurgy, Washington State College, with his paper, "Application of Physical Metallurgy." Joseph L. Newton, professor, School of Mines, University of Idaho, presented "Uses of Nonferrous Alloys." He gave statistics and compared metals such as steel, copper, lead, zinc, and aluminum in the last 20 years from the point of view of production and price in the U. S. Although this session was scheduled at the same time as the uranium session, it was well attended with about 60 there.

The ladies' program for the convention was sponsored by the Woman's Auxiliary of the Columbia Section and the Spokane and Coeur d'Alene Subsections. Mrs. L. B. Moon was Committee Chairman.

• The **Boston Section** met for dinner on January 9 at the MIT Faculty Club. President H. DeWitt Smith spoke briefly on Institute activities and discussed Tsumeb mining and milling operations. Mr. Smith retired as vice president of Newmont Mining Co. last year, but is still a member of the board. He is also chairman of O'okiep Copper Co. Ltd. and a consultant to O'okiep and Tsumeb.

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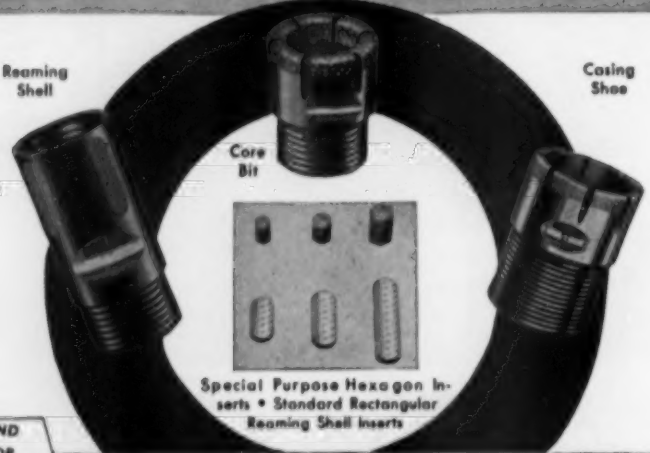

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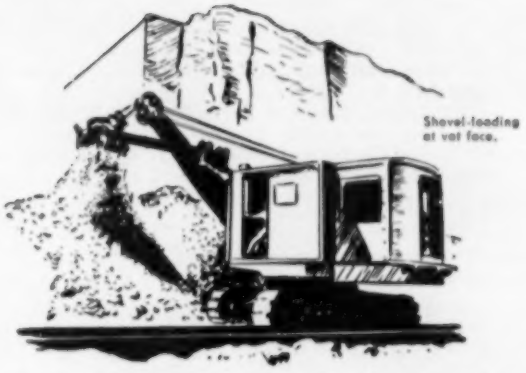
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F. WESTON STARRATT

F. Weston Starratt Joins Editorial Staff

The new assistant editor of MINING ENGINEERING, F. Weston Starratt, Jr., originally hails from the West Coast where he studied process metallurgy on the Berkeley campus of the University of California. Although born and raised in the San Francisco Bay area, he has since spent much of his time in the eastern U.S. and in Europe, commencing with military service, which at War's end, found him with the Third Army on the Czechoslovakian border. Wes returned to college in June 1946, spending the next few summers working at the old Ironton, Utah, plant of Columbia-Geneva Steel. After receiving a B.S. in metallurgy, he came to New York where he worked for his M.A. in economics at Columbia University. Returning to Europe—this time as a civilian—he took a position with the U. S. High Commission for Germany in Frankfurt. There Wes found himself in the IG Farben Bldg. writing reports on the German heavy industry and taking occasional office trips to the Ruhr or week-end jaunts to the Bavarian Alps. The next move was to Switzerland, more Alps, and the august palace of the United Nations on the shores of Lake Geneva. There Wes, who speaks French and German, worked for the Steel Committee of the Economic Commission for Europe preparing documents for committee sessions. Wes returned to the States late in 1954 to take a position in the commercial research division of a large steel export firm. His latest move was to 39th Street and the AIME, which he joined while a student at Berkeley.

To the Members of the American Institute of Mining and Metallurgical Engineers:

The regular Annual Business Meeting of the Institute will be held at 4:00 pm on the 21st day of February 1956 in the Ivy Suite of the Statler Hotel in New York City.

PLEASE TAKE NOTICE that a Special Meeting of the members of the AIME has been called for the 21st day of February 1956, to be held at the Statler Hotel in the City of New York at 4:45 pm for the purpose of considering and voting upon the following resolutions:

RESOLVED, that the name of this corporation shall be changed to AMERICAN INSTITUTE OF MINING, METALLURGICAL, AND PETROLEUM ENGINEERS, INC. and further

RESOLVED, that the second clause of Section 1 of Article I of the Certificate of Incorporation be amended to read:

"Its corporate name is AMERICAN INSTITUTE OF MINING, METALLURGICAL, AND PETROLEUM ENGINEERS, INC. and its abbreviated title is AIME" and further

RESOLVED, that the President and Secretary be and hereby are authorized and empowered to execute and file any and all documents and do all things necessary and proper to accomplish this change of name.

Dated: Dec. 21, 1955
New York, N. Y.

By Order of the Board,
Ernest Kirkendall, Secretary

(Continued from page 217)

Richard A. Harvill, president, University of Arizona, and Mrs. Harvill; R. B. Gilmore, Chairman, AIME Petroleum Branch, and Mrs. Gilmore; Joe Alford, Secretary, AIME Petroleum Branch, and Mrs. Alford; and Roy E. O'Brien, AIME Field Secretary, and Mrs. O'Brien.

Committee Members

Handling the general arrangements for the meeting were: Lyle M. Barker, T. G. Chapman, and L. L. McDaniel. Registration was handled by Chairman J. B. Cunningham, L. L. McDaniel, F. Hoffman, and J. D. Gardner, President, the AIME Student Chapter. Finances were handled by Lyle M. Barker and P. D. I. Honeyman. Technical Sessions were handled by H. E. Krumlauf. T. G. Chapman was chairman of the Entertainment Committee. Serving with him were G. J. Duff, Ed Holderness, R. F. Welch, J. A. Richards, W. R. Storms, S. L. Smith, and T. A. Snedden.

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PERSONALS

ARNOLD HOFFMAN

Arnold Hoffman of New York, has been appointed a director of Mesabi Iron Co. Mr. Hoffman is president, Towne Mines Corp. and a director of Pioneer Fund Inc. He is also a director and officer of several mining companies in Canada and Mexico, including Thompson-Lundmark Gold Mines Ltd., Quebec Cobalt & Exploration Ltd., Lac de Renzy Nickel Ltd., Junior Frood Mines Ltd., Cía. Metalurgica Mexicana, and Montezuma Lead Co. Mr. Hoffman is the author of *Free Gold, The Story of Canadian Mining.*

A. B. Drescher is division superintendent, mining, beneficiation and exploration, Lone Star Steel Co., Lone Star, Texas.

Frank Embree, engineer for the Lone Star Cement Corp., has been transferred from the New York office to the plant at Nazareth, Pa.

Walfrid Been has been appointed head, mining engineering dept., Michigan College of Mining and Technology, Houghton. Mr. Been was mine superintendent, Oliver Iron Mining Div., U. S. Steel Corp. Prior to that he was underground superintendent, Isle Royale Copper Co. Mr. Been also spent four years at the Patino tin mines in Bolivia, and at various times held positions with White Star Refining Co., Calumet & Hecla Inc., Copper Range Co., and the Michigan State Highway Dept. Mr. Been graduated from Michigan Tech in 1929 with B.S. and E.M. degrees. He succeeds **J. Murray Riddell,** who had been head of the department for ten years. Mr. Riddell will retain his rank of professor of mining engineering at Michigan Tech and will divide his time between teaching at the college and other professional activities.

James D. Crawford is now vice president and general manager, Alaskan Operations, U. S. Smelting Refining & Mining Co., Fairbanks, Alaska.

L. H. Lange, vice president and manager, Metallurgical Div., The Galigher Co., Salt Lake City, returned to the U. S. last October after an eight-month trip around the world. Mr. Lange spent two months in Tsumeb, South West Africa, as consulting metallurgist for Tsumeb Corp. Ltd., and also visited the gold mines on the Witwatersrand, the Belgian Congo, the copper belt in Northern Rhodesia, and gold mines in Southern Rhodesia. He then went to Australia and spent two months at Mt. Isa where he is consulting metallurgist for the Mount Isa Mines Ltd. Mr. Lange also visited other mining sections in Australia, including the Kalgoorlie District, Broken Hill, Radium Hill, Lake George Mines, and Mount Morgan.

Don R. Smith is production supervisor, Kaiser Aluminum & Chemical Corp., Spokane.

Carl A. Arend has been appointed general manager, Potash Div., International Minerals & Chemical Corp., Chicago. Mr. Arend was manager of International's mining and chemical operations, Carlsbad, N. M. He has been with the company since 1945.

S. P. WIMPFEN

Sheldon P. Wimpfen has resigned from the Atomic Energy Commission, Grand Junction, Colo., to become vice president, Glen Alden Coal Corp., Wilkes-Barre, Pa. Mr. Wimpfen had been manager of AEC Grand Junction Operations since that office was created in 1952. He has agreed to continue with the AEC as a consultant. Mr. Wimpfen graduated from the University of Texas College of Mines and Metallurgy in 1934, and later gained varied mining experience in the U. S., the Philippines, and Bolivia. He joined the U. S. Marine Corps in 1944 and was a construction officer on the Marshall Islands, Iwo Jima, and Okinawa. After World War II he was assistant editor of *Mining and Metallurgy.* From 1948 to 1950 Mr. Wimpfen was editor of the *Mining Congress Journal.* He then joined the AEC as assistant director of the Div. of Raw Materials, Washington, D. C.

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RAY F. GOUGH

David Kerr-Cross is mining director, International Cobalt & Silver Mining Co. Ltd., Toronto.

Dudley Thompson has been appointed professor of chemical engineering, School of Mines & Metallurgy, Rolla, Mo., and will assume chairmanship of that department Sept. 1, 1956. Mr. Thompson was professor of chemical engineering, Virginia Polytechnic Institute, Blacksburg, Va.

Azad Mardirosian is geologist, Northern Resources Corp., Salt Lake City. Mr. Mardirosian was formerly with the Texas Co., Houston.

Ray F. Gough has been appointed general mine foreman, Kennecott Copper Corp., Utah Copper Div. Mr. Gough joined Utah Copper in 1950 as an engineer trainee at the mine. Since then he has had several promotions, and was appointed safety director in September 1954. **Emmett K. Olson, Jr.,** succeeds Mr. Gough as director of safety and fire control. Mr. Olson came to Utah Copper in 1950 as a trackman. He has held various positions in the company including that of geological draftsman in the mine geology dept., engineering inspector at the mine, and assistant director of safety and fire control. **Thomas R. Carlson** has been appointed assistant general drilling and blasting foreman of the Bingham Canyon mine. Prior to joining the Utah Copper Div. in 1953, Mr. Carlson was an instructor in the mining dept. of Michigan College of Mining and Technology, Houghton.

Francis X. Tartaron is manager of ore research, Jones & Laughlin Steel Corp., Pittsburgh.

Robert W. Van Evera has been named editor of the *Mining Congress Journal*, Washington, D. C. Mr. Van Evera was a mining engineer with Calumet & Hecla Inc., Calumet, Mich. He succeeds **John C. Fox** who has been appointed assistant manager of mines, American Metal Co. Ltd., New York.

T. R. CARLSON

Gerhard C. Amstutz, petrologist, Cerro de Pasco Corp., La Oroya, Peru, is in Switzerland. Mr. Amstutz plans to visit several mines and research laboratories and the University of Heidelberg before returning to Peru in April.

J. C. Kieffer, manager, American Smelting & Refining Co., Wallace, Idaho, is a vice president of the Idaho Mining Assn. **Harry W. Marsh** has been re-elected secretary-treasurer. Other officers and directors include: **R. E. Sorenson,** vice president and geologist, Hecla Mining Co., Wallace; **Malcolm Brown,** president, Sidney Mining Co., Kellogg; **Roger H. McConnel,** chief geologist, Bunker Hill & Sullivan Mining & Concentrating Co., Kellogg; and **Edwin B. Douglas,** manager, Calera Mining Co., Cobalt, Idaho.

Paul A. Reese is field engineer, industrial hygiene dept., Kennecott Copper Corp., Hurley, N. M.

Julian E. Tobey, Jr., has been appointed director of engineering, Indiana Coal Assn., with headquarters at Terre Haute, Ind. Mr. Tobey has been associated with Blue Diamond Coal Co., Cincinnati, for the past five years as industrial sales engineer. Prior to that he was a research engineer, Fuels Div., Battelle Memorial Institute, Columbus, Ohio.

Charles R. Passavant, Jr., is research engineer, American Chrome Co., Nye, Mont. Mr. Passavant was chief mine surveyor for San Manuel Copper Corp., San Manuel, Ariz.

Rip V. Thompson is now consulting for complex and nonmetallic flotation of ores. His address is: 132 E. Broadway, Costa Mesa, Calif. Mr. Thompson's most recent position was that of superintendent, Metcalf Mining & Milling Co., Delta, Utah. Since leaving Mackay School of Mines, University of Nevada, in 1912, he has worked for several companies in the mining field, including Ophir Hill Mining & Milling Co., Ophir, Utah; Hudson Bay Mining & Smelting Co. Ltd., Flin Flon, Canada; International Smelting & Refining Co.,

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Houston M. Gallaher, formerly mining engineer, State of Kentucky, Dept. of Mines & Minerals, Lexington, is now vice president and general manager, National Hocking Coals Inc., Roseville, Ohio.

Dooley P. Wheeler, Jr., geological consultant, Salt Lake City, has been appointed vice president and general manager of Umont Mining Inc., Burlington, Vt. Before going into private consulting practice Mr. Wheeler was superintendent, Western Exploration, The American Metal Co. Ltd.

Werner Spross is now mining geologist and engineer, Bergverksselskapet Nord Norge A/S, Mo i Rana, Norway. Mr. Spross was mining engineer, Sachtleben AG, Meggen, Lenne, Germany.

Gabor Dessau who retired from Italian Government service in 1953, has continued as assistant professor, mineral deposits, University of Naples. Mr. Dessau has also been in charge of the Uranium Prospecting Center of the ENI-AGIP group, since its inception. Last October he went to the Hebrew Institute of Technology in Haifa as UNESCO expert. Mr. Dessau will remain there for one year to advise on the setting up of a geological engineering and mining dept.

Charles N. Strong, formerly head of the commercial dept. and director of purchases, Corporación de Fomento, Chile, is now executive manager, Montgomery Construction Co., Lima, Peru.

C. Philip Jenney, formerly assistant manager, exploration dept., The American Metal Co. Ltd., New York, has returned to Canada and opened a consulting office at 372 Lakeshore Highway West, Oakville, Ont.

Pedro Portaro has returned to Peru after completing a training grant in the U. S. Mr. Portaro is superintendent, Planta Sacracancha, Banco Minero del Peru, Morococha.

Charles E. Melbye and **Stuart S. Merwin** are now geological and geophysical consultants and have opened offices under the name of Melbye & Merwin at the First National Bank Bldg., Golden, Colo. Mr. Melbye and Mr. Merwin were partners in Minerals Exploration Research Corp., Golden. Mr. Melbye has worked as geologist, The Anaconda Co., Tecopa, Calif., mine engineer, Telluride Mines Inc., Telluride, Colo., and geologist and geophysicist, Bear Creek Mining Co., Golden. He was also an instructor in geology at the

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Colorado School of Mines. Mr. Merwin was engineer, Potash Co. of America, geologist, New Jersey Zinc Co., Georgia, and geologist and geophysicist, Bear Creek Mining Co. During the past year Mr. Melbye and Mr. Merwin have been consultants to the Southern Pacific RR, Hidden Splendor Mining Co., and many other firms. They are particularly interested in the integration of geology and geophysics in mineral exploration.

Alexander S. Wyner, mining engineer and geologist, Falls Church, Va., is with Ball Associates, oil and gas consultants, Washington, D. C.

Charles L. Elliot is geophysical engineer, Newmont Exploration Ltd., Jerome, Ariz. Mr. Elliot recently graduated from Michigan College of Mining and Technology, Houghton, with an M.S. in geophysics.

W. P. Dyrenforth, International Minerals & Chemical Corp., Mulberry, Fla., has transferred to the company's Central Research Laboratory, Skokie, Ill.

E. M. Lindenau has been promoted from resident manager to manager, Cía. Minera Choco Pacifico S.A., Andagoya, Choco, Colombia.

Clyde Williams, president and director of Battelle Memorial Institute, Columbus, Ohio, has been made an honorary member of the American Society of Mechanical Engineers, Columbus. He was cited as an eminent engineer. Mr. Williams was President of the AIME in 1947.

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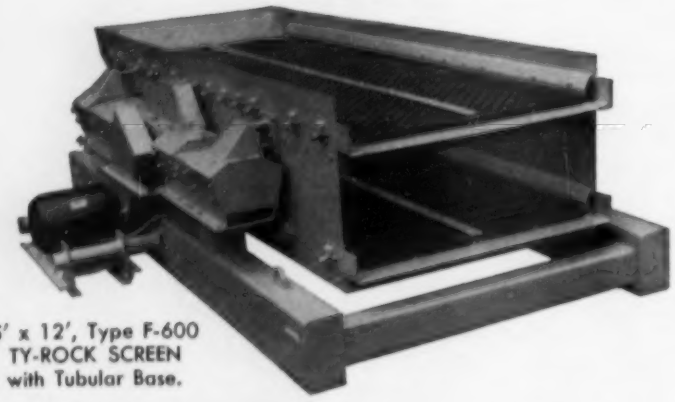

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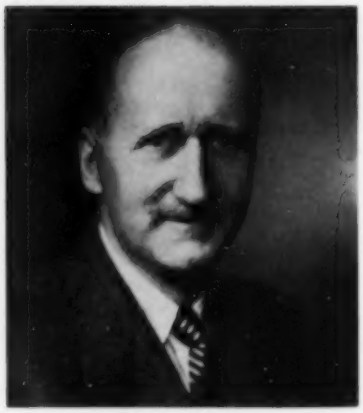

R. P. KOENIG

Robert P. Koenig, president, Cerro de Pasco Corp., New York, has been elected chairman of the board of a new wholly owned Cerro subsidiary, Circle Wire & Cable Corp., incorporated recently in Delaware.

D. M. Kentro has joined the Shattuck Denn Mining Corp., New York, as an assistant vice president. Mr. Kentro was assistant director for domestic production, Div. of Raw Materials, AEC.

M. C. Stacy is with Universal Atlas Cement Co., New York. Mr. Stacy was geologist, U. S. Steel Corp., Pittsburgh.

Sidney F. Adams is a consulting engineer at 1123 N. Cascade Ave., Colorado Springs, Colo. Before entering into private practice Mr. Adams was mining engineer with New Jersey Zinc Co., New York. Prior to that he was geologist for Empire Zinc Co., Gilman, Colo., and Cía. de Santa Gertrudis, Pachuca, Hgo., Mexico. From 1920 to 1922 Mr. Adams worked as a petroleum geologist in the California oil fields. He graduated from Stanford University, Calif., in 1917, and received an M.A. from the university in 1920.

James W. Cunningham has resigned as supervisor in the process metallurgy dept., Owens-Corning Fiberglas Corp. Mr. Cunningham is now chief chemist, Cannon-Muskegon Corp., Muskegon, Mich.

Boris J. Kochanowsky, consulting engineer and faculty member, mining engineering, Pennsylvania State University, University Park, was in Germany during the summers of 1954 and 1955 doing research in blasting and as consultant for Rheinische Kalksteinwerke Co., Wulfrath. Before World War II he was assistant to the president and general manager for this company. After the war Mr. Kochanowsky spent six years in Argentina as professor of mining engineering, University of Cuyo, and as consultant in coal and uranium mining to the government and private industry. In 1955 he obtained a doctor's degree in engineer-

ing at the School of Mines, Clausthal, Germany. Mr. Kochanowsky graduated from the School of Mines at Freiberg, Saxony, in 1929, and later attended the Universities of Kothen, Jena, and Zurich.

Warren L. Howes is manager, Western-Knapp Engineering Co., San Francisco. Mr. Howes was manager, North Central District, Western Machinery Co., Hibbing, Minn.

Robert F. Bruzewski has been appointed assistant professor, School of Mines and Metallurgy, University of Minnesota, Minneapolis. Mr. Bruzewski holds a B.S. and M.S. in mining from the University of Missouri School of Mines and Metallurgy where he has been teaching mining engineering and participating in mining research since 1947. Mr. Bruzewski graduated from the Wisconsin Institute of Technology.

Frank W. Millsaps is metallurgist, Howe Sound Co., Chelan Div., Holden, Wash. Mr. Millsaps was with Idarado Mining Co., Ouray, Colo.

T. B. Counselman has been made a partner and elected secretary-treasurer of Behre Dolbear & Co., New York. Mr. Counselman has been an associate member of the firm for some time. He has been active in the fields of iron ore concentration, and cement grinding, and was for many years engaged in developing new fields for fluidized technique in the roasting of various ores. He is a Director and Vice President of the AIME and a director of the Engineers' Joint Council.

ERNEST V. GENT

Ernest V. Gent, American Zinc Institute Inc., New York, has retired. Mr. Gent was with the Institute for 20 years, first as secretary then as executive vice president. He will continue to serve as a special consultant. Mr. Gent is succeeded by **John L. Kimberley,** secretary of the Institute.

Arnold H. Kackman, formerly with South American Gold & Platinum Co., Colombia, has joined Universal Atlas Cement Co., Leeds, Ala.

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McCombs Hardy is now a consulting geologist at 219 Wallace Bldg., Little Rock, Ark. Mr. Hardy was geologist, Arkansas Research & Development Commission, Little Rock. After graduating from Princeton University in 1938 with a B.A. in geology, Mr. Hardy was a consulting geologist in Kentucky and in Tennessee. Later he was geologist for Southwestern Minerals Corp., Little Rock. From 1942 to 1945 he was a meteorologist and personnel officer in the USAAF. Mr. Hardy then became raw materials analyst, Raw Materials Section, United Nations Relief & Rehabilitation Administration.

Raymond E. Cromar, purchasing agent, Kennecott Copper Corp., Hurley, N. M., is with the Utah Copper Div., Salt Lake City.

Russell R. Morgan, manager Cleveland Rock Drill plant, Le Roi Div., Westinghouse Air Brake Co., has retired. Mr. Morgan is succeeded by **Louis E. Dondero,** manager of Le Roi's service dept.

H. J. Schroeder, U. S. Bureau of Mines, Houghton, Mich., has transferred to Norris, Tenn.

James W. Kinnear, Jr., is vice president-operations, Tennessee Coal & Iron Div., U. S. Steel Corp., Fairfield, Ala. Mr. Kinnear was general superintendent, Edgar Thomson Works, U. S. Steel Corp., Braddock, Pa.

D. W. MITCHELL

David W. Mitchell, associate professor of metallurgy, Div. of Mineral Technology, University of California, Berkeley, is taking a year's leave of absence from the university to accept positions as acting vice president for Oil Shale Corp. and the American Mollerizing Corp., 9489 Dayton Way, Beverly Hills, Calif.

Vernon L. Mattson, manager of mining and ore processing, Kerr-McGee Oil Industries Inc., Oklahoma City, Okla. and **John A. Masters,** manager of uranium exploration, Kerr-McGee Oil Industries Inc., Denver, have assumed the duties formerly performed by **G. R. Kennedy,** who has left Kerr-McGee. Mr. Mattson joined Kerr-McGee last summer to direct expanding activities in metallurgical research, uranium mining, and milling and the mining and processing of potash. He was formerly director of the research institute at the Colorado School of Mines. Mr. Masters has been with Kerr-McGee since 1953. Prior to that he was a geologist with the Atomic Energy Commission.

J. W. Still has resigned as general superintendent, Miami Copper Co., Miami, Ariz. Mr. Still has joined his son, **Arthur R. Still,** as a consultant. Their address is Box 1512, Prescott, Ariz.

D. C. Houston, director of industrial relations, Utah Copper Div., Kennecott Copper Corp., Salt Lake City, has been named to the executive committee of the Salt Lake Safety Council.

Sidney S. Alderman, Jr., will direct the mining-geology office in Salt Lake City for United Geophysical Co. of Los Angeles. Mr. Alderman was geologist for American Metal Co. Ltd., Salt Lake City. He graduated from Massachusetts Institute of Technology.

Harry Campbell Lane has left the geological staff of Kerr-Addison Gold Mines, Virginiatown, Ont., and is mine geologist for Preston East Dome Mines, South Porcupine, Ont.

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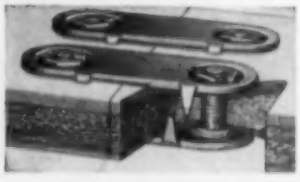

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T. D. Murphy, formerly geologist, U. S. Geological Survey, Washington, D. C., is engineering geologist, Pennsylvania Glass Sand Corp., Berkeley Springs, W. Va.

Tenny R. Fogelberg is with Marion Power Shovel Co., Marion, Ohio. Mr. Fogelberg was shift foreman, Phelps Dodge Corp., Morenci, Ariz.

Walter Bank, formerly petrographer, U. S. Bureau of Mines, Raleigh, N. C., is now geologist for the USBM at Reno, Nev.

Frank J. Maloit has been named Western manager of mines, The New Jersey Zinc Co. with headquarters at Gilman, Colo. For many years Mr. Maloit has been general superintendent of the company's Empire Zinc Div., which operates mines in Gilman, Colo., and Hanover, N. M.

R. Maurice Tripp has been appointed by **Gov. Allan Shivers** to the Governor's Advisory Committee on Atomic Energy for the State of Texas. Mr. Tripp, a Dallas consultant, will represent the mining and metallurgical industries.

C. L. Miller and his family in Chicago, en route to Argentina.

Clinton L. Miller is mine superintendent, Cía. Minera Aguilar S. A., Tres Cruces, Province of Jujuy, Argentina. Mr. Miller was with Appalachian Sulphides Inc., South Strafford, Vt.

Archie L. Carver is mining engineer, Simpson Mining Co., Grand Junction, Colo. Mr. Carver was formerly with Continental Uranium Inc., Grand Junction.

William Winther Savage is safety and ventilation engineer, San Manuel Copper Co., San Manuel, Ariz. Mr. Savage was mining engineer and level boss, Magma Copper Co., Superior, Ariz.

Horace F. Kurtz is administrative assistant, exploration dept., Kaiser Aluminum & Chemical Corp. in California. Mr. Kurtz was commodity specialist-aluminum, U. S. Bureau of Mines, Washington, D. C.

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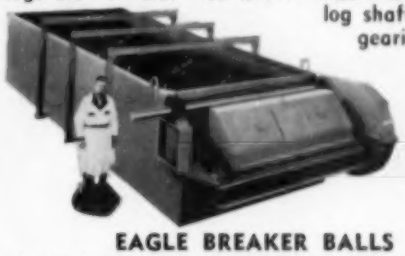

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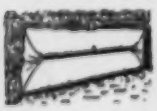

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Total AIME membership on Dec. 31, 1955 was 23,723; in addition 2825 Student Associates were enrolled.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

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OBITUARIES

John W. Bahen (Member 1951) died Nov. 11, 1955. Mr. Bahen was assistant to the president, Chesapeake & Ohio Ry Co., Cleveland. He was born in Richmond, Va., in 1905 and attended the University of Richmond. Mr. Bahen had been with the Chesapeake & Ohio Ry Co. since 1937. During that time he held various positions and was appointed assistant to the president in 1948.

Milton Alexander Caine (Member 1906) died Dec. 25, 1955 in New Rochelle, N. Y. Mr. Caine was a director and executive vice president, Tennessee Corp., New York; director and vice president, Tennessee Copper Corp.; vice president, Miami Copper Co.; and director, New Haven Copper Co. He was born in Saginaw, Mich., in 1882. After graduating from Michigan College of Mines with B.S. and E.M. degrees in 1905, Mr. Caine joined the Franklin Mining Co., Boston, Mich. Later he became mining engineer, Ducktown Sulphur Copper & Iron Co. Ltd., Isabella, Tenn. Mr. Caine joined the Tennessee Copper Corp. as superintendent of mines in 1908.

John H. Colville (Member 1928) died Oct. 24, 1955. Mr. Colville was a consulting engineer in Toronto, and president, Colville Industries Ltd., Chatham, Ont. He was born in Chesley, Ont., in 1897. After receiving an E.M. from Michigan College of Mines in 1922, Mr. Colville joined O. M. Bilharz Mining Co., Miami, Okla., as mining engineer and geologist. During the next few years he held various positions including that of mining engineer, Barnsdall Zinc Co., Joplin, Mo.; assistant superintendent, Refugio Unit, Cía. Minera Asarco, Avalos, Zacatécas, Mexico; and mechanical and mining engineer, Celite Co., Lompoc, Calif. Mr. Colville also did some independent mine examination and consulting work in the Porcupine District and in Germany. He was also with Anglo-Chilean Nitrate Corp., Tocopilla, Chile. Mr. Colville was a

member of the Canadian Institute of Mining and Metallurgy.

Clarence D. Huffine (Member 1948) died Nov. 28, 1955. Mr. Huffine was chief mine engineer, Inspiration Consolidated Copper Co., Inspiration, Ariz. He was born in Chattanooga, Tenn., in 1899. In 1923 he graduated from the University of New Mexico with a B.S. and later joined Inspiration Consolidated Copper Co. During the next few years Mr. Huffine worked on the construction of the Southern Pacific Ry from Mazatlan to Guadalajara, Mexico. From December 1928 to March 1929 he was engineer in charge of a special tunnel job near Guadalajara. He was appointed chief engineer on Jan. 1, 1948.

Otis L. Jones (Member 1936) died in May 1955. Mr. Jones was president, Illinois Clay Products Co., Joliet, Ill. He was born in Crete, Neb., in 1879. After attending Lewis Institute, Chicago, Mr. Jones worked as a draftsman in Nashville, Tenn. In 1900 he joined Harbison-Walker Refractories Co., Pittsburgh, as engineer and operator, and in 1906 went to American Refractories Co., Joliet, as superintendent. Mr. Jones became president and manager of Illinois Clay Products Co. in 1911.

Walter J. Morris (Member 1926) died Mar. 21, 1955 of coronary thrombosis in Honolulu. Mr. Morris was president, National Fuse & Powder Co., Denver. He was born in Lima, Ohio, in 1879. After graduating from Kenyon College in 1902, Mr. Morris went to the Octave Gold Mining Co., Octave, Ariz., as assayer and chemist. From 1905 to 1906 he worked for Tomboy Gold Mining Co., Telluride, Colo. Mr. Morris then returned to Octave Gold Mining Co. as cyanide superintendent. In 1909 he joined Zopopan M & M Co., La Yesca, Jalisco, Mexico. Mr. Morris started with National Fuse & Powder Co. as manager in 1912 becoming president of the company in 1913.

Fraser D. Reid (Member 1920) died Sept. 22, 1955. Mr. Reid was a consulting engineer in Toronto. He was born in Kingston, Ont., in 1881 and graduated from Queen's University in 1904 with a B.Sc. Mr. Reid's first position was that of chemist for Canada Corundum Co., Craigmont, Ont. He was made mill superintendent for that company in 1905. Mr. Reid joined Coniagas Mines Ltd., Cobalt, Ont., as mill superintendent in 1907 and later was appointed general manager. He was a mining engineer with Futterer & Reid, Toronto, for several years. Mr. Reid was a member of the Canadian Institute of Mining and Metallurgy.

Andre M. Tweedt (Member 1928) died Nov. 23, 1955 of a heart attack. Mr. Tweedt was a mining geologist and engineer in Fernley, Nev. He was born in Inwood, Iowa, in 1899. Mr. Tweedt graduated from the College of Mining, University of California, in 1928 with a B.S. and was a teaching fellow in geology at the university from 1928 to 1929. He then went to Consolidated Coppermines Corp., as assistant geologist. In 1934 Mr. Tweedt became superintendent, W. M. Mining & Milling Co. Inc., Mina, Nev. Mr. Tweedt was later manager, Allied Annie Laurie Gold Mines Inc., Sevier, Utah.

Necrology

Date Elected	Name	Date of Death
1941	Richard G. Amidon	Unknown
1936	Benjamin V. Becker	Feb. 5, 1955
1943	D. F. Brown	November 1955
1906	Milton A. Caine	Dec. 25, 1955
1947	Keith F. Finlay	Oct. 6, 1955
1937	Teodoro Flores	February 1955
1927	Adnah G. Kostenbauder	Unknown
1931	H. H. Lester	Nov. 11, 1955
1952	V. H. Montgomery	Unknown
1921	R. Hartley Sherwood	Dec. 2, 1955
1948	A. A. Smith	Nov. 26, 1955
1950	Irving S. Tillotson	Apr. 8, 1955
1912	Carl J. Trauerman	Dec. 17, 1955
1920	Marshall S. Walker	Dec. 2, 1955
1905	Samuel S. Wyer	Nov. 30, 1955

Clarence Aldro Wright

An Appreciation by
David L. Forrester

The passing of C. A. Wright (Member 1912) on June 10, 1955 at the age of 69 was a real loss not only to his many friends but to the mining profession.

Mr. Wright was a native of Marquette, Mich. He was a graduate of the George Washington University, the Yale Sheffield School, and did post-graduate work at the Royal School of Mines in Berlin.

He was associated with the Bureau of Mines from 1911 to 1920, first in charge of research in ore-dressing at the Experimental Station in Joplin, Mo.; then in charge of the Bureau's Experimental Station in Moscow, Idaho; and later at the Salt Lake City Station. From 1920 to 1928 he was employed by the Atesina Mining Co. in northern Italy where he was in charge of building concentrating mills and later became manager of the company.

Returning to the U. S., he was employed by the Standard Oil Co. of New Jersey in research on hydrogeneration of coal. He returned to Federal service with the Bureau of Mines and in 1941 joined the Office of Production Management and subsequently was with the War Production Board. He continued with the Government until he retired in 1953.

He was a member of the Mining and Metallurgical Society of America, the Cosmos Club of Washington, D. C., and the Chi Phi Fraternity at Yale.

During his Federal service, he was particularly helpful to the young engineers and metallurgists entering the Government service.

Survivors are his widow, Dorothy Gibson Wright, two daughters, Mrs. William A. Van Allen, and Mrs. David W. Heron, five grandchildren, and his brother, Charles Will Wright.

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Coming Events

Feb. 20-23, AIME, Annual Meeting, Statler and New Yorker hotels, New York.

Feb. 27-29, Rocky Mountain Section, American Assn. of Petroleum Geologists, 6th annual convention, Municipal Auditorium Annex, Denver.

Mar 1, AIME, Utah Uranium Subsection, 7:30 pm, Arches Cafe, Moab, Utah.

Mar. 3, AIME, Colorado Plateau Section, annual meeting, Grand Junction, Colo.

Mar. 8-9, Society of Exploration Geophysicists, 9th annual Midwest meeting, Fort Worth, Texas.

Mar. 12-16, National Assn. of Corrosion Engineers, conference and exhibition, Statler Hotel, New York.

Mar. 21-23, American Power Conference, Sherman Hotel, Chicago.

Mar. 28-31, AIME, Nevada Section, Reno.

Mar. 28-31, Cordilleran Section, Geological Society of America, convention, Reno, Nev.

April 6, Pennsylvania Anthracite Section, Necho Allen Hotel, Pottsville, Pa. John Cipyak will speak on "Machine Accounting as Applied to Mining Industry."

Apr. 9-11, AIME, Open Hearth and Blast Furnace Conferences, Netherland Plaza Hotel, Cincinnati.

Apr. 9-11, Canadian Institute of Mining and Metallurgy, annual meeting, Chateau Frontenac, Quebec City.

Apr. 23-25, Symposium on Rock Mechanics, Colorado School of Mines, Golden, Colo.

Apr. 25-26, American Assn. of Petroleum Geologists, Conrad Hilton Hotel, Chicago.

May 3-5, AIME, Pacific Northwest Regional Conference, Olympic Hotel, Seattle.

May 7-9, American Mining Congress, Coal Convention, Netherland Plaza Hotel, Cincinnati.

May 17-18, Rocky Mountain Petroleum Sections, joint meeting, Gladstone Hotel, Casper, Wyo.

June 16-23, Fifth World Power Conference, Vienna.

June 17-23, American Society for Testing Materials, annual meeting, Hotel Chalfonte-Haddon Hall, Atlantic City, N. J.

Aug. 23-25, National Council of State Boards of Engineering Examiners, Hotel Statler, Los Angeles.

Sept. 4-11, 20th International Geological Congress, Mexico City.

Sept. 26-28, AIME Rocky Mountain Minerals Conference, Salt Lake City. Technical papers will represent all branches, including the Petroleum Div.

Sep. 29-Oct. 1, Society of Exploration Geophysicists, 26th annual meeting, New Orleans.

Oct. 1-4, American Mining Congress, Mining Show, Shrine Auditorium, Los Angeles.

Oct. 8-10, AIME, Institute of Metals Div., Allerton Hotel, Cleveland.

Oct. 14-17, AIME, Petroleum Branch, Biltmore Hotel, Los Angeles.

Feb. 26-29, 1957, AIME Annual Meeting, Roosevelt and Jung hotels, New Orleans.

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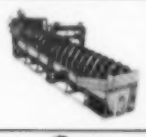
DENVER Spiral **CLASSIFIER**		6" Simplex to 60" Duplex	Has many improvements. For instance, lower bearing placed above pulp level, arrangement of feed, overflow and direction of rotation result in maximum efficiency. Rake-type and Denver-Finney classifiers also available.	Bulletin No. C5C-B
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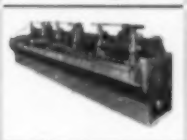
DENVER "Sub-A" **FLOTATION**		16" x 16" to 56" x 56"	More large plants are installing Denver "Sub-A's" for their entire flotation job — roughing, scavenging, cleaning and re-cleaning — because they give maximum recovery at a low cost per ton. Dependable, low-cost, simplified continuous operation.	Bulletin No. F10-B81
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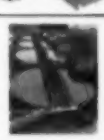
DENVER Spiral Rake **THICKENER**		3' x 3' to 80' x 12'	Enclosed, running-in-oil head motion. Patented spiral rakes move settled solids to center discharge with continuous motion, rapid removal of solids tends to eliminate overload. Wood, Steel or rubber-covered Tanks available.	Bulletin No. T5-B5

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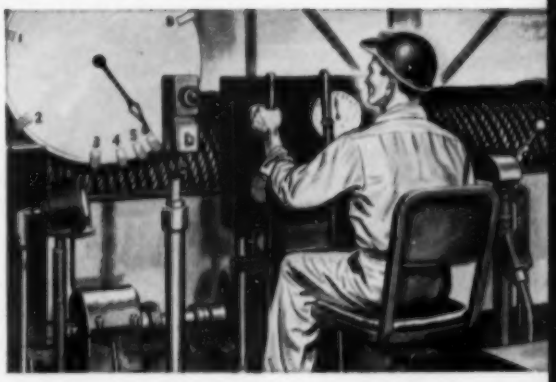

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